

Thesis/
Reports
Larson,
D.S.

THE SUITABILITY OF VARIOUS MARKETS FOR
USING SMALL DIAMETER PONDEROSA PINE
TO SUSTAIN FOREST HEALTH AND
FIRE-RISK REDUCTION PROGRAMS IN
NORTHERN ARIZONA

THE SUITABILITY OF VARIOUS MARKETS FOR USING SMALL DIAMETER PONDEROSA PINE TO SUSTAIN FOREST HEALTH AND FIRE-RISK REDUCTION PROGRAMS IN NORTHERN ARIZONA

By Debra Larson
Department of Civil and Environmental Engineering
Northern Arizona University, Flagstaff, AZ 86011

INTRODUCTION

The restoration of forests to healthy conditions while reducing fire risks requires a combined approach of thinning overstocked small diameter trees and the reintroduction of surface fires. The critical component of thinning, however, is expensive and generates large volumes of woody fiber that cannot be left in the forests because of fire, insect, and disease reasons. Projects within the ponderosa pine dominated urban-wildland interface of Coconino County in northern Arizona show that thinning involves the cutting and processing of (Larson and Mirth, 1999, Larson, et al, 2001):

- Nearly 100% of the 4" dbh and smaller trees; resulting in the cutting of over 800 trees per acre on those units that have never been thinned to as few as 60 trees per acre on previously thinned units.
- 90% to 100% of the trees in the 5" to less 9" dbh class; resulting in the cutting and removal of 55 to 200 trees per acre.
- 50% to 80% of the trees in the 9" to less than 16" dbh class; resulting in the cutting and removal of 50 to over 100 trees per acre.

Estimates suggest that the recoverable merchantable wood fiber range from 5.5 ccf/acre (Larson and Mirth, 1998) to 17.7 ccf/acre (Larson and Mirth 1999) depending upon stand conditions and prescription. If thinned, the greater Flagstaff, AZ fire risk zone of approximately 94,000 acres (GCFP, unknown-a) could yield between 24,816 to 99,828 truckloads¹ of logs.

This by-product (small diameter trees) of forest health and fire risk reduction programs could be used to defray the costs of treatment if suitable markets existed for this fiber.

The current state of the wood-based industry in northern Arizona, however, is one that is nearly extinct. In 1986, there were three sawmills operating in Coconino County and over twelve logging companies with a combined employment of over 530 (County Business Patterns, 1988). By 1996, the sawmills had disappeared and only two logging companies remained. Wood sector employment dropped to 50 (County Business Patterns, 1996).

¹ This assumes that only 60% of the risk zone is treated and a truck load of logs is about 10 ccf. The remaining 40% is not thinned because of a variety of issues like wildlife corridors or endangered species habitat.

The implications of this limited industrial base to the future of regional forest health and fire-risk reduction programs are economically daunting as exemplified by the recent activities of the Grand Canyon Forests Partnership (GCFP). The GCFP is an alliance of fifteen environmental, business, and governmental organizations in Flagstaff, Arizona. The GCFP is dedicated to restoring forest health, to managing forest fuels to reduce the threat of catastrophic fire in the urban wildland interface, and to assessing the ecological, economic, and social dimensions of forest restoration efforts (GCFP, unknown-b).

Their first project, a research and demonstration project that was divided into three contracts, was started in the Fall of 1999. The project dragged on much longer than anticipated, because of the difficulty in finding suitable markets for the merchantable logs, as well as an overabundance of non-merchantable trees. It was necessary to renegotiate the pre-commercial phase of one contract that represented three units of few available merchantable trees and 500 to 800 trees per acre of less than 5" dbh trees. In addition, the GCFP found it necessary to work as a middleman to facilitate the moving of logs, at cost, to a new post and pole operation. Based upon contract information alone, it is estimated that GCFP lost about \$5,000 on this 332-acre project. This estimate does not include any administrative costs the GCFP or Forest Service incurred. In addition to the economic losses, the GCFP received negative publicity from sources such as the Southwest Forest Alliance (SWFA, unknown) who perceived the project as merely a pretext for commercial logging.

Their second project, located adjacent to the first within the Fort Valley 10K area, consisted of three approximate 100-acre units with three different forest-health based prescriptions (Larson, et al, 2001). The entire project was awarded to one logger on May 8, 2001 to hand-fell. The contract reflected the logger's previous experience with this type of project and the continued lack of suitable fiber markets. It will cost the GCFP \$45,000 (or approximately \$200 per treated acre) to complete.

Without suitable markets, the ability of the GCFP or other entities like the Forest Service to continue funding thinning projects at the rate of \$200/acre plus administrative costs will be quickly limited.

The work of Lynch, et al (2000) in the ponderosa pine dominated forests of the San Juan National Forest in Colorado, however, suggest that forest restoration projects can achieve ecological objectives and pay for themselves if:

- suitable markets exists,
- the treatments are carefully planned, and
- the costs of harvesting and transportation are controlled.

What then are suitable markets for small diameter ponderosa pine thinned from the forests of northern Arizona? This question is particularly relevant to a region that is starting anew in trying to develop a wood conversion capacity that can contribute to the program of sustaining forest health and fire-risk reduction programs through the manufacture and sale of wood-based products.

Answers to this question are provided here via the use of a structured analysis process known as the decision matrix.

DECISION MATRIX METHODOLOGY

The decision matrix methodology is a rational multi-attribute decision-making technique similar to the Kepner-Tregoe method (Kepner and Tregoe, 1965), but expressed in matrix form (Ulrich and Eppinger, 2000). It is particularly useful during the early stages of problem solving where details are impossible to fully predict, but it is still necessary to converge and select a solution (Pugh, 1995).

This methodology involves the evaluation of alternative solutions, in this case wood fiber uses and products. Each use is numerically evaluated by comparing its performance in a number of categories to a benchmark product. Upon completion of the numerical evaluation, a total score is tallied for each use. This score provides an objective rating of how suitable the fiber use may be in sustaining forest health and fire risk reduction programs in northern Arizona.

The successful use of this decision method hinges upon the initial work of setting up the matrix. This initial work includes:

1. Generate a comprehensive list (or space) of all possible wood uses.
2. Reduce the space of possible solutions to a smaller, more realistic set of alternatives for analysis.
3. Establish the criteria by which the uses will be evaluated against.
4. Assign criteria weighting factors to reflect the relative importance of each criterion.
5. Select a benchmark use.

The Space of Possible Wood Uses

In classic decision-making, the identification of the space of all possible solutions can be time consuming and would consist of searching the literature, interviewing lead users, consulting with experts, examining related products, and searching patents. Luckily, for our problem this work has already been completed. Dramm (1999) has compiled the space of existing technologies for using small diameter wood, which is repeated here as Figure 1. This figure organizes product opportunities as a function of processing and log quality. Primary breakdown mills are found at the top, secondary manufacturing at the bottom. Products that require high value logs are located to the left, whereas products that can make use of lower value logs are at the right side of the figure. Value in this case is interpreted as logs that are larger in size and contain fewer defects.

Reduce the Space of Possible Solutions

Figure 1 represents over thirty-two potential products and product combinations. A detail evaluation of all of these possibilities would be daunting with results that would be hard to synthesize due to size. The second step then in setting up the decision matrix is to reduce the space to smaller number of viable product alternatives suitable to the conditions of northern

Arizona and the small diameter ponderosa pine resource. Two guiding principles were used to screen the various uses; yielding a smaller number of truly viable alternatives.

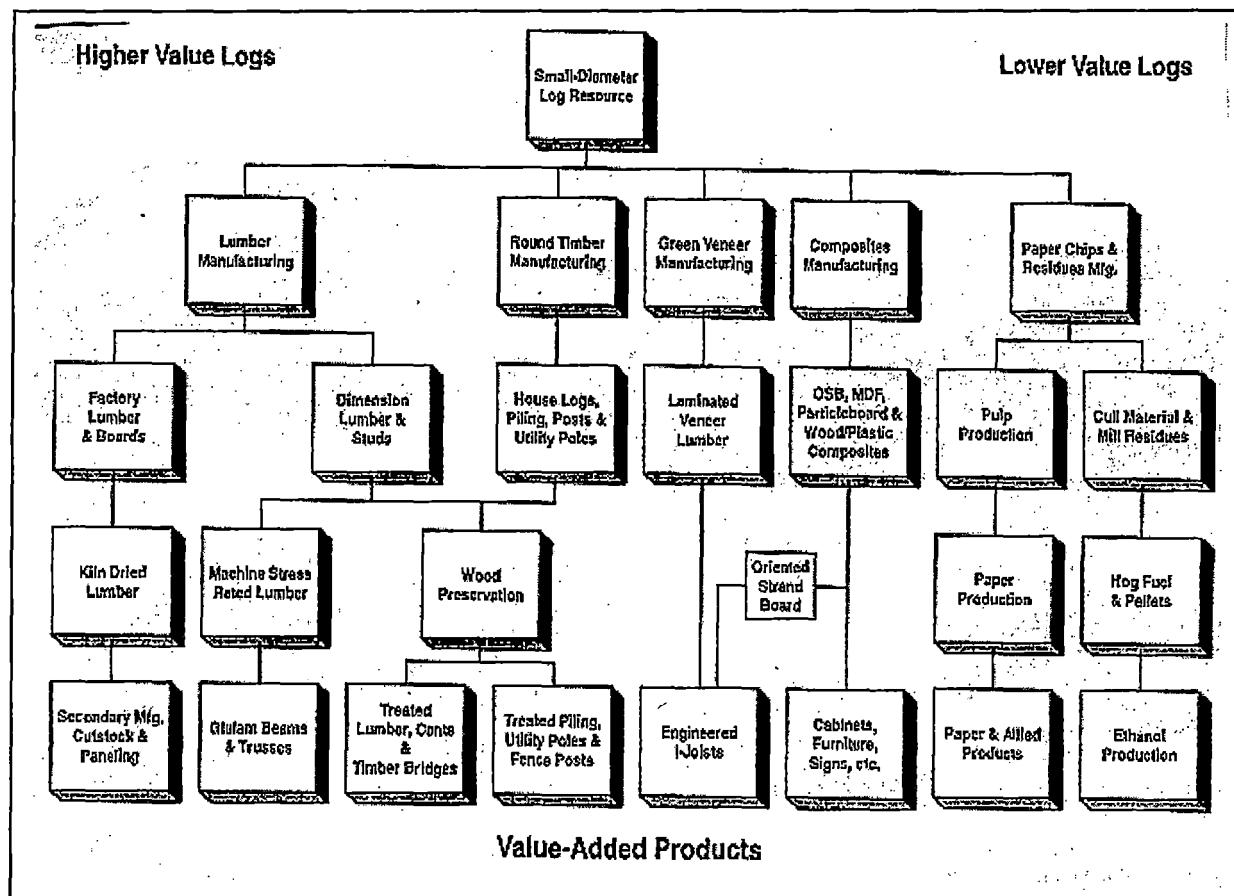


Figure 1. Potential Products for Small-Diameter Utilization (Dramm, 1999)

The two guiding principles were:

1. The projected size of a northern Arizona based forest health and fire-risk reduction program is large². Given this, it was felt that only those industries that could convert, on a sustained basis, large volumes of wood from small diameter trees should be considered. Small-volume, independent users were not considered, because they would not be able to sustain, on the basis of input volume, a restoration program of any significant level.
2. Those uses that represented primary manufacturing approaches were considered over secondary products. Secondary products are manufactured from one or more primary products. Examples include wood boxes, kitchen cabinets, wood I-joists composed of structural panels, or laminated veneer lumber. Secondary products are not feasible if the primary materials are not readily available. In addition, the location of secondary products manufacturing is a key factor in determining market success. Proximity to market is more

² Earlier work (Larson and Mirth, 1998) suggested that there are over 600,000 acres in the Coconino National Forest alone that may need some treatment with the potential of generating 2.5 million ccf of fiber from 5" to 12" dbh tree class.

important than proximity to raw material (Polzin, 1994). Market research shows limited opportunities for “value-added” wood products in rural areas (Irland Group, 1991) like that of northern Arizona.

Upon application of these two guiding principles, seven products, listed in Table 1, were deemed suitable for further analysis.

Label	Product
A	Oriented Strand Board (OSB)
B	Plywood
C	Particleboard (Part'b'd) and Medium Density Fiberboard (MDF)
D	Lumber and Boards
E	Mechanical Pulp
F	Ethanol
G	Roundwood use cluster

Table 1. Possible Uses for Small Diameter Ponderosa Pine in Northern Arizona

Evaluation Criteria

Critical to the success of the decision matrix process is the choice of evaluation criteria. This criteria reflects the requirements and constraints that possible solutions must meet. Evaluation criteria at this stage of decision making are at a relatively high level of abstraction, but are distinct enough to differentiate between fiber uses. The criteria chosen for this analysis are provided below.

Criterion 1. Initial Costs and Flexibility

The required initial capital investment in a manufacturing infrastructure provides an indication of the risk of establishing such a facility in northern Arizona. Of particular concern is the uncertainty of a sustainable supply of wood fiber from potential thinning projects. Project initiation and future planning in the region are at low levels as exemplified by the Coconino National Forest's 2000 and 2001 project planning. It's been estimated that the planned projects, if implemented, could yield an average of 44,719 ccf/year of pulp and saw logs (Mater, 2001). But, this is only a fraction of the fiber required to supply, on a yearly basis, a modern manufacturing facility like an OSB plant. Because of this, those manufacturers with that can start at a smaller scale, reflected by lower initial capital investment, and can grow and add infrastructure as supply improves will get higher ratings in this criterion.

Criterion 2. Discharge

This is a qualitative evaluation of the manufacturing process relative to the type and amount of waste products generated and the accompanying discharge procedures. Those technologies that either produce little waste or are able to mitigate the impacts of the discharge are rated higher.

Criterion 3. Water Usage

Water conservation is an important component sustaining the populations and industries of the arid Southwest. Those industries with less water requirements will have an easier time becoming established and sustaining their operations. They shall be rated higher for this criterion.

Criterion 4. Wood Material Properties

This criterion assesses the compatibility of material characteristics to the technical demands of the various uses. This assessment, however, only addresses wood coming from the currently merchantable size classes of trees 5" dbh and larger. Those manufacturing processes that can effectively make use of large quantities of small diameter material shall be rated higher.

Small-diameter, slow-growing ponderosa pine trees that exist in crowded stands is a resource that presents manufacturing and use obstacles. This wood, is called black jack pine because of its black bark, is different in many ways from the mature ponderosa pine resource, characterized by its yellow to orange bark. It is so different that Fahey and Sachet (1993) suggest treating it as a resource separate from mature yellow ponderosa pine. The one characteristic of black jack pine that is so troublesome is the occurrence of juvenile wood.

Juvenile wood is wood formed by cambial regions influenced by the activity in the apical meristem (the crown of the tree) (Rendle, 1960). It is generally located within the inner portions of the stem cross-section. It is not readily identifiable through casual means and there is no sharp demarcation between juvenile and mature wood. Juvenile wood cells are shorter than those of mature wood. In addition, the microfibril angle in the S-2 part of the secondary cell wall is characteristically greater in juvenile wood (Haygreen and Bowyer, 1996). These characteristics of juvenile wood translate into a variety of product related problems, regardless of species. These problems include:

- Warping of lumber and veneer products. Juvenile wood tends to shrink as much as three times more than mature wood (McAlister and Clark, 1992) in the longitudinal direction. A product that contains both mature and juvenile wood can experience, during uncontrolled drying, differential shrinkage along the grain that results in warping.
- A reduction in lumber grade yields. Juvenile wood is often lower in density and strength than that of mature wood (Bendtsen, 1978, Senft et al, 1985, Senft et al, 1986, and McAlister and Clark, 1991) that is reflected in grade downfall.
- Low kraft pulp yields. Juvenile wood contains higher lignin and hemicellulose content and lower cellulose content (Haygreen and Bowyer, 1996) that can lead to reduced kraft pulp yields.
- In-service moisture problems. Composite board products manufactured from wood with a large percentage of juvenile exhibit greater thickness swelling and linear expansion (Pugel, et al, 1989 and 1990).

Unfortunately, very little is known about the extent and nature of juvenile wood in the black jack ponderosa pine resource of northern Arizona. Voorhies and Groman (1982) examined the relationship between longitudinal shrinkage and rings from the pith from ponderosa pine logs in

the 6 to 11 inch scaling diameter classes taken from northern Arizona. This study suggested that at about 20 rings from the pith, the percent longitudinal shrinkage settles down to and remains at about .2%; a shrinkage value normally expected for mature ponderosa pine. In an earlier study, however, Voorhies and Jameson (1969) concluded that the age of maturation for ponderosa pine based upon both fiber length and fibril angle is about 50 years. Some additional data recently collected (Mirth and Larson, 2000) gives an indication of the extent of juvenile-type wood. One hundred and twenty ponderosa pine logs ranging in size from 3.5" to 8.22" dib were taken from the forests around Flagstaff, AZ and were examined. The first 20-year portion of the log cross section was found to make up, on the average, 58% of the small end cross-section.

Criteria 5, 6, 7, and 8. Size Suitability

These criteria assess the suitability of the woody material, grouped according to four size classes, relative to product and manufacturing needs. This assessment accounts for log or chip properties and qualities like vs. manufacturing limitations. The four size classes corresponding to each criterion are:

- Slash, B&N: Slash is branches and tree tops. B&N refers to bark and needles separate from woody component of slash.
- $3'' \leq \text{tree dbh} < 5''$: This category of wood is often called biomass. It is measured in tons of green logs or bone dry units in a clean chip form.
- $5'' \leq \text{tree dbh} < 9''$: Logs from these trees are often referred to as pulpwood and quantified in units of 100 cubic feet (ccf), chords, or green tons. These logs are cut to a top measuring 4" or 5" inside bark diameter (dib).
- $9'' \leq \text{tree dbh} < 12''$: Merchantable logs coming from these trees are often referred to as saw logs and are quantified in units of ccf or 1000 board feet (Mbf). Logs from the smaller trees in this class are often bucked to a 5" dib top and the larger trees to a 6" dib top. The 12" limitation represents the regional definition of small diameter in response to market conditions. The local operators are able to readily find markets for logs taken from trees larger than 12" dbh.

Those manufacturing processes that can readily use material within the various size classes are rated higher.

When working with trees and logs, it useful to know the size of the merchantable log that can be obtained from a tree. The following table, Table 2, provides an estimate of log potential for small diameter ponderosa pine trees based upon standing tree dbh. These estimates are based upon a 20% bark thickness at the butt, a 12 inch stump, and a stem taper inside bark of .15 inches per foot of stem. Each tree will differ some from these log estimates.

Criterion 9. Revenue Potential

This criterion is evaluates the product's revenue potential using the most currently available data.

Tree dbh (inches)	Log diameter ¹ (inches)	Log length (feet)
6	4	9
7	4	14.4
8	5	13
9	5	18.4
10	6	17
11	6	22.4
12	6	27.7

¹Small end, inside bark

Table 2. Merchantable Log Estimate Based Upon Tree Size

Criterion 10. Jobs

Northern Arizona's rural economy is a weak one that is highly dependent upon the few sectors of tourism, government (forest service, state and county), and education (NAU). It looks to diversify its economic base through industries that can provide long-term, good paying jobs. Those industries that can directly provide these types of jobs are rated higher in this criterion. No attempt was made to evaluate the influence a particular option might have on secondary job growth.

Criterion 11. Market Outlook

This criterion evaluates the product's potential in the market by examining demand and supply projections over both the short and long term. Higher ratings mean that the product has good market potential that suggests a reasonable return on the initial investment.

Weighting of Criteria

Weighting factors are assigned to the criteria to reflect the relative importance of the various criteria. These weighting factors, based upon 100 percentage points, are shown in column three of Table 3 and reflect the authors' interpretation of the importance of each criteria to the context of northern Arizona. Additional weight is given to: criterion 1 initial facility costs, criterion 4 wood fiber material properties, criterion 7 suitability of wood from 5" to less than 9" dbh trees, criterion 9 revenue potential, and criterion 11 market outlook.

Benchmark Use: Orientated Strand Board

Another important aspect to setting-up the decision matrix is the selection of an appropriate benchmark product from which all other uses are compared. In this study the authors chose orientated strand board, OSB, as the benchmark because:

1. It is a well-understood technology.
2. The production process and economics are well documented.
3. It is a product that is well suited to effectively utilize ponderosa pine wood fiber.

Oriented strandboard is a structural panel product manufactured from three to five layers wood strands compressed and bonded with phenol formaldehyde resins. The strands of each layer are oriented to lie in one direction, and each layer is laid perpendicular to the adjacent layer to produce a cross-laminated product. OSB is primarily used for roof, floor, and wall structural sheathing applications in light-frame construction.

Criterion 1. Initial Costs and Growth Flexibility

To take advantage of economies of scale, OSB plants have become large manufacturing facilities growing in size from output capacities of 100 to $160 \times 10^6 \text{ ft}^2/\text{year}$ (3/8" basis) to more than $400 \times 10^6 \text{ ft}^2$. Spelter, et al (1996) estimated that the initial capital costs for a OSB facility with a $300 \times 10^6 \text{ ft}^2$ production capacity was \$70,000,000. This estimate included land, engineering, site preparation, buildings, equipment, installation, and start-up capital.

Criterion 2. Discharge from an OSB Manufacturing Plant

The production of OSB is a relatively benign process. Emissions, such as volatile organic compounds and chemical emissions from the respective drying and pressing operations are easily controlled with air scrubbing equipment. However, some wastewater from the emissions stack is produced.

Criterion 3 - Water Usage During Manufacturing

Water usage is small with daily draws in the neighborhood of 500 gal/day for the control of stack emissions and to cool the cutter disks (Bullock, 1996). Those plants that precondition logs prior to debarking and flaking require a one-time large water use to fill the hot ponds; occasional water is added to these ponds due to losses through log absorption, evaporation, and leaking. It is believed that any new facility located in or near northern Arizona would need soaking ponds.

Criteria 4 - Input Fiber Material Requirements for the Manufacture of OSB

Since current economic strategies encourage the building of large-scale facilities, a larger capacity plant with a yearly production of $300 \times 10^6 \text{ ft}^2$ of 3/8" thick board is assumed here. It has been reported that the manufacture of 1 ft^3 of board requires between 1.8 to 2.0 ft^3 of wood in the form of pulpwood size logs (Spelter, 1996). Assuming 4" and 5" logs, a facility of this size would require about $17 \times 10^6 \text{ ft}^3$ of input wood fiber per year. If each thinned acre generates approximately 700 ft^3 of fiber in the 6" to 12" dbh grouping then the thinning of approximately 24,000 acres/year will supply enough fiber to sustain a large OSB facility.

The most important characteristic of a species that affects its suitability for OSB manufacture is its specific gravity (Haygreen and Bowyer, 1996). As a general rule, lower density species are preferred for two reasons. One, the lower the wood density, the higher the board strength at any given board density. Two, low density wood reduces through-the-mat density variability. The traditional species of choice for OSB is aspen with a specific gravity (based on oven dry weight and green volume) of .35 (FPL, 1999). Ponderosa pine, however, may be fall into the suitable range of species for OSB production with its specific gravity of .38. Recently, the GCFP

conducted an undocumented trial run of small diameter ponderosa pine logs for OSB at the Louisiana-Pacific (L-P) Corporation's Montrose, Colorado manufacturing plant that normally utilizes 100% hardwood species. The results of this test were favorable; prompting visits to Flagstaff by L-P personal to scout out log supplies and transportation options. Nothing more beyond these initial inquiries have developed, however, due to expensive transportation costs - Montrose is over 400 miles away by truck from Flagstaff - and declining OSB prices.

Criteria 5, 6, 7 and 8 – Size Class Suitability for OSB

In order to control strand quality, which impacts panel strength and dimensional stability, the entire process of turning round logs into strands is handled on-site. Thus, the incoming raw material is in the form of green round logs. The suitability of each size class to OSB is as follows:

- Slash, Bark and Needles: Not used in the manufacture of OSB.
- $3'' \leq \text{dbh} < 5''$: Logs from this size class of trees are too small for effective handling and processing.
- $5'' \leq \text{dbh} < 9''$: Logs from this class of tree sizes are commonly used in the production of OSB strands.
- $9'' \leq \text{dbh} < 12''$: Although logs from this class of tree can be used in the production of OSB flakes, they could be put to a higher value use such as appearance grade boards if the capacity existed.

Criterion 9. Revenue Potential for OSB

A 1996 analysis of published OSB information (Spelter, 1996, Spelter, et al, 1996) reveals the following plant cost information. Cost to manufacture, including capital depreciation and input fiber costs, was projected to be \$4.55/ft³ of finished OSB produced at a 300 x 10⁶ ft² facility. Of this, wood fiber costs accounted for 32%; equivalent to \$1.04/ft³ on an incoming wood basis, with an average fiber to product recovery of 71%. The projected net revenue varies as a function of the volatile OSB panel market as discussed in more detail below in criterion 11. Using a range of prices for 3/8" board from \$ 160 to \$220 per thousand square feet, revenue could range from \$.57 to \$2.49 per cubic foot of finished product.

Criterion 10. Job Creation Directly Due to an OSB Facility

Spelter, et al (1996) estimate that the 300 x 10⁶ ft² 3/8" board plant would generate approximately 130 manufacturing-related jobs.

Criterion 11. Market Outlook

Demand

Like most wood products, structural panel demand is tightly linked to the construction market, and in particular, residential construction. It has been estimated that housing starts in the U.S. will average 2.0 million per year over the next fifty years, a gain of 200,000 starts over the

previous forty-year average. In addition, the size of these new units will continue to increase. Single family units will grow from a current average size of 2160 ft² to 2600 ft² by 2050 (Haynes, 2001).

Of this market, OSB will continue to gain ground at the expense of softwood plywood. The use of OSB per square foot of floor area in new housing will rise until about 2010. OSB consumption growth after 2010 will be derived primarily from residential upkeep and improvement and other applications found in shipping and manufacturing. The consumption of OSB/waferboard in 1996 on a 3/8" basis was 13.6 billion ft² vs. the 18 billion ft² of softwood plywood. It is projected that OSB/waferboard consumption will increase to 24.6 billion ft² by 2010, whereas softwood plywood is expected to decline to 11.4 billion ft² (Haynes, 2001).

In 1996, the U.S. OSB production equaled 9.3 billion ft². Imported board, primarily from Canada, met the remaining demand of 4.3 billion ft². U.S. OSB production capacity is projected to grow to 14.3 billion ft² by 2010, while board imports grows to 10.3 billion ft² (Haynes, 2001).

Price

The short-term market price for OSB depends strongly on production capacity. In the mid-1990s, twenty new plants producing about 8 billion ft² of board came on line. In response, panel prices plunged to selling levels below production costs. The price of a benchmark indicator, 7/16 inch OSB produced in the North Central region, was in the \$120s per thousand square feet for the first half of 1997 (Random Lengths, 1999).

By 1999, the market recovered, as exemplified by the near record price of \$260 per for the 7/16 inch OSB panel in the North Central region. With prices up, however, plans for five new mills were announced and production capacity is predicted to leap by 5 billion ft² by the end of 2002, an increase of about 25% (Random Lengths, 2000). Without new markets and uses for OSB, this increase in capacity will predictably lead in the next five years to price reductions, mill closures, delayed expansions, mergers and downsizing, or shifting to specialty products (Schuler and Adair, 2001).

Over the long term, the 2000 RPA timber assessment (Haynes, 2001) predicts only limited movement in long-term prices for OSB/waferboard. In terms of a deflated price index based upon the 1982 7/16-inch base, the OSB price historical and future projections are shown in Figure 2. This figure suggests that the wide fluctuations of price experienced during the 1990s and predicted to occur into the early 2000's as a function of production capacity may settle out. Prices will increase at a moderate pace.

One other factor to consider when evaluating market outlook and revenue opportunity is the proximity of any competing industries. The closest OSB facilities are operated by Louisiana Pacific; one is in Montrose, Colorado and the other in Chilco, Idaho. Competition for fiber by another OSB plant is currently not an issue.

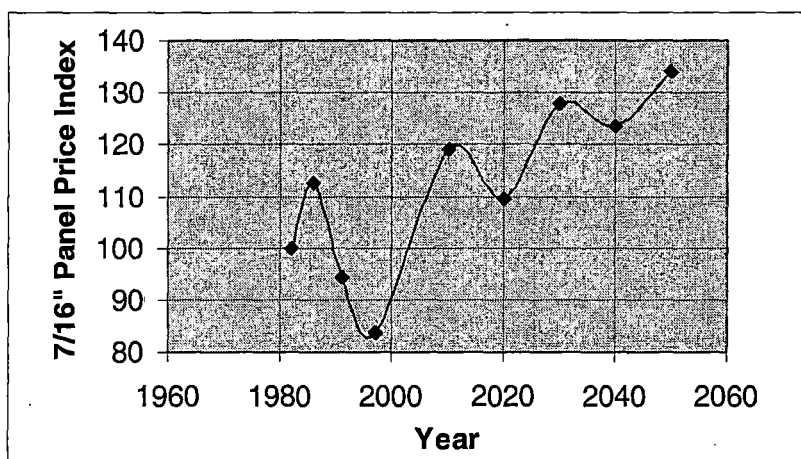


Figure 2. OSB/Waferboard Long-term Projected Price Behavior

The Decision Matrix

			A	B	C	D	E	F	G
	Criteria	Wts. (%)	OSB	Plyw'd	Part'bd	Lumber & Boards	Mech. Pulp	Ethanol	Round Wood
1	Initial Cost/Flexibility	12.5	3						
2	Discharge	6.25	3						
3	Water Usage	6.25	3						
4	Wood Properties	12.5	3						
Size Suitability:									
5	Slash, B&N	6.25	3						
6	3" ≤ dbh < 5"	6.25	3						
7	5" ≤ dbh < 9"	12.5	3						
8	9" ≤ dbh < 12"	6.25	3						
9	Revenue Potential	12.5	3						
10	Jobs	6.25	3						
11	Market Outlook	12.5	3						
	Total Score								
	Rank								
	Weighted Total Score								
	Weighted Rank								

Table 3. Incomplete Fiber Use Decision Matrix

Once the alternative uses have been identified, the evaluation criteria chosen, and the benchmark selected, the matrix is assembled. It is provided in Table 3; serving as a tool and record for evaluating each use against the benchmark within each of the ten criteria. A relative scoring system of numbers ranging from 1 through 5 are placed in each cell depending upon how the alternative rates in comparison to the benchmark. The relative scores mean:

- 5 = performs much better than the benchmark
- 4 = performs better than the benchmark
- 3 = performs the same as the benchmark
- 2 = performs worse than the benchmark
- 1 = performs much worse than the benchmark.

In those instances when there is not enough information available to permit a comparative evaluation, a score of "3" is assigned.

PRODUCT DETAILS

The following discussion provides the background information needed to competently judge and score each alternative within the various criteria. The results of the authors' scoring are provided in Table 10 located in the following section titled Decision Matrix Results and Discussion

USE B - PLYWOOD (PLYW'D)

Plywood is the forerunner to OSB in the structural panel market. It is made up of a number of veneers, where a veneer is a thin sheet of wood obtained by rotating and cutting peeler logs. The veneer is spread with thermosetting synthetic glue and cross-laminated (adjacent layers have the wood grain at right angles) into a plywood panel. Plywood is used for structural and architectural purposes. Major applications for structural plywood are in residential and commercial construction and in industrial markets such as pallets, crates, and concrete forms. Most structural plywood is made from softwoods. Architectural plywood serves appearance-type decorative needs in applications such as wall paneling and furniture manufacture and is often are manufactured from hardwoods.

The softwood plywood industry originally developed on the West Coast and was concentrated there for several decades because of the availability of large high-quality peeler logs, mostly of Douglas Fir. The industry shifted to the South with advances in resin technology and manufacturing equipment making it possible to manufacture plywood from southern pine logs averaging 10 to 12 in. in diameter. The closest manufactures of plywood to northern Arizona are the two Boise Cascade facilities located in Elgin and Emmett, Idaho.

A large number of species can be used to produce plywood. The various species are assigned, according to strength and stiffness, to one of five different groups. Group 1 species have the highest strength characteristics, and Group 5 the lowest properties. Plywood made up of species from groups 1 to 4 can be used for structural applications. Ponderosa pine is a group 3 species (APA, 1997).

Since the late 1970's, plywood has been loosing key markets to OSB because OSB is less expensive. As of early June 2001, 3/8" CD exterior southern plywood from western mills in Texas, Louisiana, and Arkansas was selling net, f.o.b. mill for \$263 per thousand sq. ft. Comparable southern OSB was priced at \$200 (Random Lengths, 2001). Similar differentials are present for other grades and mill locations.

Plywood production in 2000 fell to 19.68 billion ft², while OSB output rose to 20.65 billion ft². In the RPA 2000 projections, softwood plywood consumption is projected to decline slowly to 10 billion ft² by 2015 (Haynes, 2001). This reduction is being attributed to three things: the substitution of OSB for plywood in residential construction, a constrained supply of suitable raw material, and mills choosing to produce veneer for the growing laminated veneer lumber (LVL) industry instead of plywood (Schuler and Adair, 2001).

Small log utilization efficiencies in plywood are low. Full sheet veneer recovery can be as low as 27% for a block diameter of 5" to a high of 60% for 10" and better diameter blocks (Willits, et al 1996). Lower recovery rates coupled with the need for higher quality incoming logs results in poor product revenue projections as discussed below.

Spelter (1996) notes that wood accounts for the largest share of manufacturing costs for southern pine plywood. In 1995, this cost accounted for 52% of the estimated total cost-to-product of \$6.93/ft³. Even though plywood sells at a premium, it is not enough to counteract the incoming wood costs and provide attractive net revenues. In this analysis, net revenues were as low as \$.63/ft³ based upon a relatively high selling price of \$236 per thousand sq. ft. of 3/8 inch thick panel.

On the average, the typical southern pine plywood mill is approximately 24% smaller than the average OSB facility, reflecting in a lower number of jobs. However, input fiber requirements are approximately the same as that of OSB due to the lower recovery rates associated with veneer peeling.

USE C – PARTICLEBOARD & MEDIUM DENSITY FIBERBOARD

Particleboard (part'bd) and medium density fiberboard (MDF) are nonstructural panels that are different in some important ways, but are also similar in others. As a result, there are few publicly available manufacturing and economic analyses that separate the two products into distinct categories.

The size and geometry of the wood particle, the amount of resin used, and the density to which the panel is pressed generally differentiates particleboard types. Lately, these manufacturers have been using a smaller than typical wood particle produced through mechanical means to manufacture a panel product that competes with MDF in furniture core markets. In contrast, MDF uses wood that has been reduced to individual fibers and fiber bundles of low bulk density via a thermomechanical pulping process. Once the mat of fiber, resin, and wax has been formed, the remainder of the MDF manufacturing process is similar to that of particleboard.

Particleboard and MDF manufacturing was once based upon cheap mill residue consisting of planer shavings, slabs and chips, and the dust from sawing and sanding. This residue was available for essentially the cost of hauling. This situation is no longer true due to the numerous sawmill closures of the late 1980s and early 1990s and the now common use of residues for on-site energy production. As a result, sawmill residue is a highly desirable commodity and the particleboard/MDF industry faces stiff competition for this raw material.

The cost of the wood raw material makes up one-fourth to one third of the total costs associated to the production of particleboard. It is so costly that any anticipated expansion in particleboard capacity is based upon cheaper agri-fiber instead of wood (Spelter, 1999).

The specific gravity of the species is the most important raw material characteristic for the production of particleboard. Like OSB, lower density woods are preferred and ponderosa pine is acceptable.

Plant capacity tends to be, on the average, 20 to 30% smaller than the average $300 \times 10^6 \text{ ft}^2$ 3/8 inch OSB plant. Lower plant capacities reflect fewer jobs. And lower capacities coupled with high fiber utilization efficiencies equate to less input fiber requirements.

Working from Spelter (1996), which relies on the use of cheap mill residue as the input wood source, the total cost-to-product, including capital depreciation and overhead, is $\$3.96/\text{ft}^3$ in 1995 dollars for particleboard. Wood costs make up 22% of this total. This wood cost component converts to an approximate incoming cost of $\$.70/\text{ft}^3$, using an 80% recovery rate. It is important to note that the incoming wood residue is often clean and partially dried. Additional costs for storage and handling, debarking, drying, chipping must be added to this analysis, if round wood is the raw material.

Manufacturing cost information for MDF is not readily accessible. One 1994 study (Rosenfield, 1994) suggests that MDF manufacturing costs could range from $\$3.59/\text{ft}^3$ for 38 pounds per cubic feet (pcf) board to $\$5.01/\text{ft}^3$ for 53 pcf board.

Particleboard is priced competitively; selling at a slightly lower price than OSB. 3/8" and 5/8" industrial particleboard manufactured in western Oregon is priced, net f.o.b. mill, at \$180 and \$220 per thousand square feet, respectively (Random Lengths, 2001). Net revenue projection based upon Spelter's work with mill residue as the raw material source and the current 3/8" panel price is approximately $1.80/\text{ft}^3$.

In contrast, MDF is generally priced at a premium to particleboard. 5/8" MDF produced at plants west of the Mississippi has a current price of \$335 per thousand square feet; \$100 more than comparable particleboard.

Market	Particleboard	MDF
Custom laminators	16%	16%
Kitchen & bath		
Stocking distributor	17%	22%
Home furniture	20%	19%
Office furniture	6%	5%
Door core	4%	---
Underlayment	9%	---
Molding & millwork	---	15%
Other	12%	18%

Table 4. Particleboard/MDF 1997 North American Market Share (Spelter, 1999)

Particleboard, along with MDF, is used as cores stock in a variety of secondary, residential construction products as shown in Table 4. Interestingly, this table also shows the grow of MDF in the molding and millwork markets replacing traditional products like ponderosa pine boards.

The RPA 2000 predicts moderate increases of nonstructural panel consumption (including particleboard and MDF, hardwood plywood, insulating board, and hardboard) to 25.8 billion ft² (3/8" basis) in 2010 from 21.0 billion ft² in 1996. Of this 1996 total, particleboard and MDF accounted for 60% of total consumption. Future outlook in the four major nonstructural panel markets vary considerably with insulating panels and hardwood plywood declining, but particleboard and MDF showing continued growth that parallels output in furniture, cabinetry, and underlayment in new single-family residences (Hayne, 2001). There appears, however, to be some predicted over capacity in production as indicated by price projections. The nonstructural panel deflated price index strongly influenced by particleboard and MDF is projected to remain steady over the long term as seen in Figure 3.

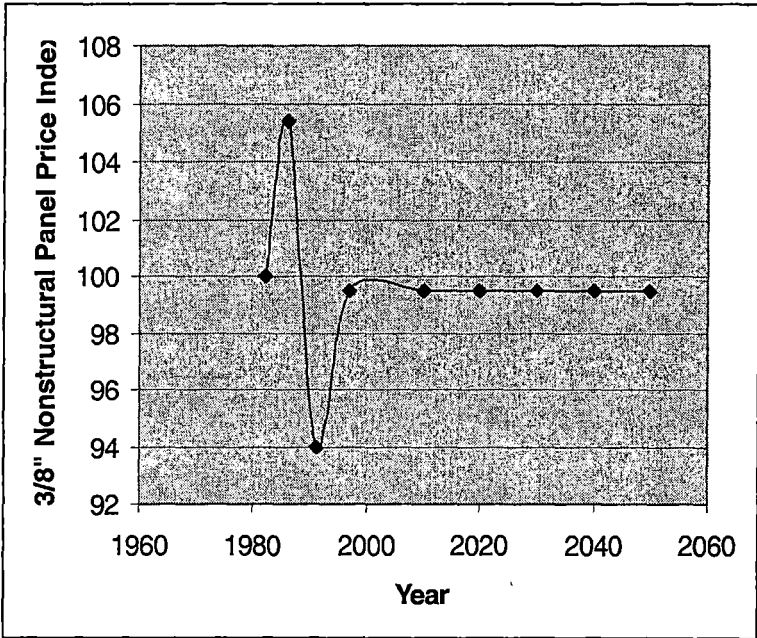


Figure 3. Nonstructural Panel Long-term Projected Price Behavior via Deflated Index

The closest particleboard plant to northern Arizona is Ponderosa Products in Albuquerque, NM. The closest MDF plant is Oro-Pine MDF in Oroville, CA (Random Lengths, 1998).

USE D – DIMENSION LUMBER AND BOARDS

Historically, mature ponderosa pine was a commercially important southwestern timber resource that supported a lumber industry built upon the recovery of high-value factory and shop products, paneling, and dimensional lumber (Maeglin, 1987). These products were known for their dimensional stability and for yielding substantial volumes of clear cuttings for use as molding and stock for door and window frames and drawer parts (WWWPA, 1995). Mature ponderosa pine was the species of choice for millwork.

Older sawmilling technologies, however, were very inefficient, converting only 30 to 60% of the log to solid product. Larger logs provided better recoveries and better revenue opportunities. The processing of only small logs in an older, large-log sawmill provides negative returns (Wagner, et al, 1998). Recent advances in optimization and sawing techniques, however, are proving that a modern, high-speed mill can provide a reasonable return on investment via smaller logs. Comparisons made via a sawmill simulator between conventional stud sawmills and modern high-speed, small-log sawmills (Wagner, et.al, 2000) demonstrate this clearly. Their results showed that the lumber produced at a conventional western stud sawmill from small diameter timber less than 11-in. dbh provides negative returns. In contrast, lumber from trees as small as 7-in. dbh produced at a modern small-log mill provides positive returns where variable costs as well as the costs to harvest and deliver logs are covered.

It is believed that black jack ponderosa pine produces lumber and boards of lower grade that are susceptible to further degrade in uncontrolled environments where moisture fluctuates. There are only a few existing studies, however, that documents these issues. These studies include the assessment of lumber potential from small diameter ponderosa pine harvested from the GCFP's research and demonstration project in the Fort Valley project area near Flagstaff, AZ (Lowell and Green, in press). Lumber was sawn from 150 trees ranging in size from 6 to 16 inches dbh. Half of the trees were sawn into 2-inch dimension lumber (with some 1-inch jacket boards) and the other half into 1-inch appearance-grade boards. After kiln drying, the lumber was surfaced and graded. An analysis of the lumber's market value was also completed. A summary of their results are listed below:

- Tree and log characteristics: Average tree age was 90 years old, ranging from 50 years to 120 years. Log scaled defects were very small, at less than 1.5% of the total cubic log volume.
- Lumber recovery on a volume basis: The mean cubic recovery from logs sawn for dimension and appearance lumber was, respectively, 42.7% and 40.4%.
- Lumber value: Based upon WHPA November 1999 summary prices, the mean value of the appearance grade lumber was \$268 per hundred cubic feet gross log scale basis, while dimension lumber was only \$215. Lumber grade recovery for both visually-graded appearance and dimension lumber is provided in Table 5.

Structural Light Framing Dimension Grades	Percent volume recovered	Appearance Grades	Percent volume recovered
Select Structural	<1	No. 1 Common	3
No. 1	4	No. 2 Common	22
No. 2	46	No. 3 Common	66
No. 3	31	No. 4 Common	7
Economy	9	Moulding	<1
1" Boards	>9	3 Clear	<1
		1 Shop	1
		2 Shop	1

**Table 5. Lumber grade yield from Northern Arizona Ponderosa Pine Logs
(Lowell and Green, in press)**

It is generally believed that mechanical grading can enhance the value of lumber because it can more finely sort lumber into its appropriate strength grades than visual grading can. As a second phase of this lumber study, the 2 by 4 dimension lumber was sent to the University of Idaho to determine the potential benefits of mechanical grading by machine stress rating (MSR) techniques (Gorman, 2001). A total of 707 pieces ranging in length from 6 to 16 feet (6,224 board feet) were evaluated. The total sample had a mean density of .408. The results of the grading and testing are provided in Tables 6, 7, and 8.

Structural Light Framing Grades	No. Pieces	Recovered Volume (Bd. Ft.)	Recovered Volume (%)	No. Pieces Tested	Mean Density	Mean MOE ¹ (psi, 10 ⁶)	Mean MOR ¹ (psi)
Select Structural	21	141	2.4	17	.431	1.374	7841
No. 1	39	287	4.9	35	.41	1.248	5511
No. 2	200	1555	26.7	181	.407	1.106	4418
No. 3	224	1883	32.3	60	.404	.995	3846
Economy	223	1961	33.7	----	----	----	----
Total	707	5827	100				

¹Unadjusted test results – not for use in design.

Table 6. Yield and Mechanical Properties from 2 by 4 Ponderosa Pine Lumber from Northern Arizona Graded by Structural Light Framing Rules (Cisternas, 2000)

Light Framing Grades	No. Pieces	Recovered Volume (Bd. Ft.)	Recovered Volume (%)	No. Pieces Tested	Mean Density	Mean MOE ¹ (psi, 10 ⁶)	Mean MOR ¹ (psi)
Construction	104	763	13.1	94	.409	1.193	5257
Standard	219	1739	29.8	192	.407	1.079	4198
Utility	179	1517	26.0	----	----	----	----
Economy	205	1815	31.1	----	----	----	----
Total	707	5834	100				

¹Unadjusted test results – not for use in design.

Table 7. Yield and Mechanical Properties from 2 by 4 Ponderosa Pine Lumber from Northern Arizona Graded by Light Framing Rules (Cisternas, 2000)

The large volume of economy grade lumber, having little merchantable value, was primarily the result of warp. Upon comparing Tables 6 and 7 to Table 5, it is apparent that the warp and resulting grade downfall occurred sometime after the lumber left the sawmill grading station, and not during the actual kiln drying process. Presumably, this finished lumber dried even further while in-route to Idaho or in-storage. Unfortunately, this warping behavior is not unexpected as is suggested by a few older studies (Arganbright et al 1978, Blake and Voorhies, 1980, Mackay and Rumball, 1972, Markstrom et al 1984) and anecdotal reports on small diameter ponderosa pine.

The visual grade recovery per the light framing rules is less than that needed by a mill to ensure adequate revenues. Confidential conversations with sawmill consultants and mill personal from various Inland West mills suggest that the percentage of recovered Standard and Better needs to be 53 to 55%. Table 7 is showing only 43% recovered to the Standard and Better grades.

	Grade	No. pieces	Volume (bd.ft.)	% Yield
Alternative 1	1650Fb-1.5E	28	214.7	9.4
	1450Fb-1.3E	46	366.7	16.0
	1200Fb-1.2E	22	169.3	7.4
	900Fb-1.0E	193	1484.0	64.9
	Rejected	5	50.7	2.2
Alternative 2	1500Fb-1.4E	57	430.7	18.8
	1200Fb-1.2E	64	520.0	22.8
	900Fb-1.0E	167	1276.0	55.8
	Rejected	6	58.7	2.6
Alternative 3	1450Fb-1.3E	117	909.3	39.8
	900Fb-1.0E	171	1317.3	57.6
	Rejected	6	58.7	2.6
Alternative 4	1200Fb-1.2E	169	1304.0	57.1
	900Fb-1.0E	116	900.0	39.4
	Rejected	9	81.3	3.6

Table 8. MSR grades for 2 by 4 lumber produced from small diameter ponderosa pine from Northern Arizona (Cisternas, 2000)

The market opportunity for MSR lumber is in the engineered wood products arena of metal gusset plated trusses, wood I-joists, and glued laminated beams. These products are engineered to serve in high stress situations and often require MSR grades of 1650Fb-1.5E and higher. Only a small amount of the ponderosa pine of this study would fall into this grade class. The yield of MSR lumber, if representative of the larger forest, would not readily justify the added investment in MSR equipment and processing steps (Gorman and Green, 2001) under current market structure.

The study, however, suggests that a sawmill specializing in appearance grade may have opportunities for success especially if the lumber was furthered processed into cut-stock material. Earlier work on lumber from small diameter trees from the Pacific Northwest (Lowell et al 2000) indicates that 6-inch wide boards are higher in value as cut-stock than lumber, and the No 3. Common boards realized the largest uplift when evaluated for cut-stock. About 60% of the No. 3 Common boards in Table 5 were 6-inches or greater in width; a significant quantity warranting further analysis as cut-stock.

A large stud mill producing in excess of 100 million board feet of solid sawn product per year would require upwards of $16 \times 10^6 \text{ ft}^3$ of fiber, which would be obtained from the thinning of more than 23,000 acres. These large mills employ about 135 to 190 people. A smaller 30 person facility producing 20 million board feet of product would require upwards of $3.2 \times 10^6 \text{ ft}^3$ of fiber obtained from thinning 4600 acres per year.

Spelter, et al (1996) approximated the operating costs, which included capital depreciation but not input wood costs, for a 100×10^6 board feet facility at \$1.44/ft³ of finished product or about \$.80/ft³ gross log. This is in contrast to a Western species stud lumber sales price of \$3.36/ft³ of lumber which occurred during the Fall of 1995 (Spelter, et al, 1996) or the appearance grade lumber value of \$2.68/ft³ gross log provided above.

The net revenue for a typical facility that can readily sell its wood residue, however, is not simply the lumber sales price minus wood costs and operating costs, but should include revenue from the sale of pulp chips, shavings, and sawdust. These revenues are estimated at \$2.00/ft³ for pulp chips and \$.50/ft³ to \$.70/ft³ for particleboard residue. The revenue expectation based on the 1995-1996 values, without regard for incoming wood costs, could possibly be in the neighborhood of \$1.94/ft³.

Prior to the late 1980's, a number of medium to large sawmills operated in northern Arizona. Except for the Fort Apache Timber Company (FATCO) in Whiteriver, the remaining mills (Precision Pine mill in Heber, Reidhead & Sons Logging in Fredonia, and Reidhead Brothers Lumber mill in Nutrioso) are 6 to 13-man operations each using around 5 million board feet of logs when operating. FACTO owns 68% of the Arizona conversion capacity with their primary source of fiber being ponderosa pine from the White Mountain Apache reservation. It is estimated that they can convert between 68 million to 91 million board feet of logs into lumber (Temple, et al, 1999).

The long-term market outlook for lumber consumption is tied directly construction. About 65% of the lumber produced in 1996 was used for construction. Residential upkeep and improvements are becoming a dominating factor in softwood lumber usage. The U.S. consumption of softwood lumber is projected to grow from 49.1 billion board feet in 1996 to 55.4 billion board feet to 2010 with imports expected to supply about 41% of this demand (Haynes, 2001).

USE E – MECHANICAL MARKET PULP

More than three-quarters of the world's wood pulp never leaves the mill in which it is produced; instead it is used in another part of the facility to make paper and paperboard. In some cases, however, a paper mill may not produce a certain type of pulp, or it may be a non-integrated facility without a pulping capacity of its own. As a result, the paper mill will fill its requirements from other mills, or it will purchase pulp, known as market pulp, from outside market pulp suppliers. To reduce the complexity of a market analysis, this study focuses on market pulp vs. the wide variety of paper and paperboard products obtained from pulp. In addition, the primary difference among the various paper and paperboard manufacturing processes is the pulping process where pulp makes up a large part of the costs of finish production.

Most paper-grade pulps are produced by chemical processes, but some are made by mechanical methods. These mechanical-based pulps include stone groundwood, thermomechanical pulp (TMP), chemi-thermomechanical pulp (CTMP), and bleached chemi-thermomechanical pulp (BCTMP). Mechanically produced pulp has been chosen for analysis instead of chemical (either sulfate – also known as kraft – or sulfite) pulps, because of the economic and scale advantages. Mechanical pulp has lower production costs, lower labor costs, and much lower capital costs per ton of product than kraft processes. It also is free of the rotten cabbage smell so characteristic of kraft mills. In addition, kraft-pulping technology has larger economies of scale requiring large-scale facilities, whereas mechanical pulping provides more flexibility in facility size. On the downside, mechanical processes have high electrical energy demands with revenue and profit potential highly dependent on energy costs.

Of the 58,261,000 metric tons of wood pulp produced in the U.S. in 1996, 9.25% was groundwood or thermo-mechanical pulp (Miller Freeman, 1997). There are no CTMP/BCTMP mills currently operating in the U.S. and only one mill is being planned – the \$300 million Aspen Bay Pulp & Fibre located in Menominee, Michigan with start up sometime in 2002 (Paperloop, 2000). Seventy-four percent of the worldwide capacity of BCTMP is located in Canada due to their low energy costs and proximity to suitable wood species like aspen and birch (Cannel and Cockram, 2000).

Mechanical pulping reduces pulpwood to individual fibers through mechanical energy where the wood is physically torn apart. As a result, little material is lost; approximately 90% to 95% of the incoming wood is turned into pulp. These high yield pulps, however, contain high lignin contents, resulting in paper that yellows with age, is low in strength, and has relatively poor surface quality. Mechanical pulps are ideal for newsprint and low-quality mechanical printing grade paper such as that found in phone directories.

Of the mechanical pulps, BCTMP is particularly attractive, as it is competitive with bleached krafts. BCTMP hardwood has sold at an average 90% to 95% of southern hardwood bleached kraft (Miller Freeman, 1997). It has been accepted in the printing/writing sector in the Far East for a number of years and is gaining acceptance in Europe.

Chemi-thermomechanical and bleached chemi-thermomechanical pulp are not purely mechanical pulps, but involve the addition of chemicals (sodium sulfite and chelating agents) to the chips prior to refining. Hydrogen peroxide is generally used to bleach the CTMP pulp to brightness levels of 85+ ISO. CTMP and BCTMP have a number of advantages over TMP pulp. The chemical pretreatment of the chips permits a less destructive separation of fibers from the wood, resulting in a higher content of longer fibers. The fiber is more flexible, providing higher sheet density and higher burst and tensile strength. Major markets for CTMP and BCTMP not only include newsprint, mechanical printing paper, but also absorbent products like tissue and baby diapers. It is also moving into printing/writing sector that other mechanical pulps cannot access.

Producers closely guard BCTMP production and consumption statistics making predictions about market outlook difficult. Most of the market for BCTMP in the U.S. and Canada is for tissue and towel grades of paper. But in 1997, the U.S. adopted a more flexible specification that no longer limits high-yield pulps in free sheet grades to 10%. This easing plus predicted increases in demand for printing/writing grade paper is expected to increase BCTMP consumption. In addition, pulp prices are expected to increase at a moderate pace into 2001 in response to worldwide increases in demands without little capacity build-up (McLaren, et al 2000). And as pulp prices increase, the price differential between chemical and BCTMP grades tend to narrow, further increasing investment attractiveness in BCTMP (Cannel and Cockram, 2000).

The pulp market suffers from widely cyclic behavior with sharp inventory swings and rising or falling prices. Capital investment in the market pulp industry usually comes in surges during periods of rising prices and profits. New mill construction takes two or three or more years. Once the wave of new capacity comes on line, the market may weaken, resulting in oversupply and declining prices. As profitability declines, companies rein in capital spending, slowing down

capacity expansion, and setting the stage for the next period of market tightness (Miller Freeman, 1997).

The suitability of a wood species for mechanical pulping is a function of fiber length, fiber flexibility, and density. Dense species are generally not used in mechanical pulping processes because of the associated fiber-shattering problem. Lodgepole pine and ponderosa pine are among the low fiber, low density softwood pulpwood species that are preferred for pulping and papermaking. The range of species suitable for BCTMP, however, has not been fully explored, but it is believed that ponderosa pine may be physically suitable with the integration of a system to handle problems caused by the large amount of resin in pine-type woods. It has been suggested, however, by Willits et al (1996) that stems smaller than 5" in diameter will affect pulp quality due to an increase in fines.

Spelter et al (1996) estimate the manufacturing costs for a smaller-than-typical BCTMP facility of 165 tons of dry pulp/day to be \$393/dry ton of pulp. Input fiber requirements with a 10% moisture content are estimated at $13.25 \times 10^3 \text{ ft}^3/\text{day}$, which is equivalent to $22.52 \times 10^3 \text{ ft}^3/\text{day}$ at 80% moisture content. This type of fiber consumption equates to $7.9 \times 10^6 \text{ ft}^3/\text{year}$, equal to the thinning of approximately 11,300 acres/year. With almost a one-to-one input to output efficiency, the cost to manufacture, without regard for incoming wood costs, can be restated in terms of output fiber as approximately \$4.89/ft³. This number, however, is very sensitive to power costs, as energy expense is the largest component of the total operating budget. With an assumed sales price of \$798/dry ton, revenue expectations are in the neighborhood of \$405/dry ton, equivalent to \$8.21/ft³. Net revenue expectations are subsequently high, especially if incoming wood costs can be controlled.

Spetler et al (1996) indicate that the 165 ton/day facility will generate approximately 4500 gallons of waste water per air dry ton of pulp; this waste water has a fairly high organic content. In comparison to a kraft facility, the generation of air-borne particulates and organics is small, but must still be removed from the air prior to emission to the surrounding environment.

At one time, the opportunity for developing new pulp and paper capacity in northern Arizona was marginal due to the existence of Abitibi's (formerly Stone Container) linerboard and newsprint facility in Snowflake, AZ. Prior to its conversion in about December of 1998 to a 100% recycled product, this mill consumed about 580,000 tons of green chips and pulpwood as well as 360,000 tons of recycled paper (Bennett, 1996).

There is currently a new greenfield thermomechanical pulp and paper mill being planned for Belen, New Mexico. This \$750 million facility, called New Era Forest Products, LLC, will primarily utilize ponderosa pine chips to produce approximately 200,000 tons per year of finish product like lightly coated groundwood paper.

USE F – ETHANOL

The production of ethanol from woody material is considered at this time an emerging use for the small diameter wood. Ethanol is currently produced mostly from corn, (Biofuels, 1998;

Kryzanowski, 1998a), but new technologies developed by the National Renewable Energy Laboratory (NREL) are improving the prospects for wood conversion (USDOE, 1993).

The Department of Energy believes that ethanol use may reduce oil imports, slow the depletion of oil resources, and may in fact help the environment (USDOE, 1993). For example, ethanol is blended with gasoline in many cities in the Western United States to increase the octane of the fuel while reducing carbon monoxide levels (Kane and LeBlanc, 1989). A second environmental benefit is that there is no net release of CO₂ produced by the combustion of the ethanol (USDOE, 1993). In the coming years, automakers plan to produce vehicles that will use ethanol as an alternative fuel (Reitman and Christian, 1997).

Currently, ethanol demand is driven by the federal and state Clean Air Act requirements mandating the use of oxygenates in winter gasoline. Ethanol consumption California, Arizona, Nevada, Oregon, and Washington increased from 154 million to 214 million gallons per year from 1992 to 1995 (QL, 1997). Ethanol production on the West Coast in 1997 was only 14 million gallons per year; 6 million produced in California and 8 million being produced in Washington. Demand was being met by ethanol produced in the Midwest.

The process for producing ethanol consists of breaking up the wood fiber and treating it to promote a maximum amount of fermentation of the xylan and cellulose components of the wood. During this process, the lignin in the wood is separated out and is available for use as a burning fuel or for processing into other products. A number of items are needed to carry out the production process (USDOE, 1993). The ethanol facility must be co-located at a power plant which would supply the necessary steam and power. The power plant boiler can burn the gaseous and solid fuels given off by ethanol production (methane and lignin). A disc refiner is needed to process chips into small pieces to start the refinement process. Steam at 50 pounds per square inch gauge (psig) and 150 psig, and compressed air, is needed to aid in the fermentation of the chips. Cooling water is needed to maintain process efficiencies.

The new technology to produce ethanol from wood has been tested on a laboratory scale, but has not yet been assembled in a working plant.

To better understand the economics of a wood-to-ethanol manufacturing facility located in northern Arizona, Mark Yancey of NREL (1999) completed two analyses of our situation. He examined the costs and the internal rate of return (IRR) for a 7 million gallon per year facility located at the Cholla Power Plant near St. Johns with a yearly raw material supply of 141,000 bone-dry-short tons (BDT) costing, respectively \$20/BDT and \$40/BDT. His results, which were based upon many assumptions that could be fine tuned if warranted, suggested that the respective IRRs were 7.5% and -.8%; neither of which prove to be good investments. A summary of the raw material inputs and Yancey's model are provided in Table 9.

It was estimated that over 11,500 acres per year would need to be thinned to supply the feedstock volume of 141,000 BDT/year. In this projection, all harvested trees 5" to less than 11" dbh and the tops and branches of the 11" and larger trees went as feedstock.

The fiber costs of \$40/BDT and \$20/BDT as shown in Table 9 reflect two different scenarios: with and without additional subsidies. Based upon the earlier reported work, harvesting and hauling costs to a facility 90-miles away, would cost about \$48.50/ccf or \$40/BDT.

	\$20/BDT Raw Material Costs	\$40/BDT Raw Material Costs
Plant ethanol capacity	7,000,000 gallons per year	7,000,000 gallons per year
Plant life	20 years	20 years
Ethanol yield per BDT	49.6 gallons per BDT	49.6 gallons per BDT
Ethanol selling price	\$1.30 per gallon	\$1.30 per gallon
Total capital investment	\$26,847,000	\$27,088,000
Annualized loan payment	\$2,806,000	\$2,831,000
Net production costs/year	\$8,188,000	\$9,522,000
Feedstock costs/year	\$2,820,000	\$5,640,000
Cost of raw materials, % , of selling price	16.7%	31.2%

Table 9. Raw Material Inputs and Plant Model for Ethanol Production

Although a 7,000,000 gallon per year wood-to-ethanol manufacturing facility could utilize a great deal of small diameter wood and provide potential economic benefits to the local community, the cost of the input fiber precludes further analysis. The work reported on here suggests that the cost to harvest and transport the raw woody materials must be reduced to at least \$24.30/ccf to make the manufacturing economics more attractive to potential investors without any state or federal subsidies.

USE G – ROUNDWOOD USE CLUSTER

So far this analysis has considered only commodity-type products where profits are derived from economies of scale and speculation on margins between raw material purchases and finished product sales. These products require a steady and large supply of raw wood of specific characteristics, a highly automated and mechanized manufacturing process, and the marketing know-how to make profits via sales margins.

The roundwood use cluster, however, represents a different strategy that manufactures products for niche, small-scale markets that can be quite volatile. Production requires smaller volumes of raw material, and can be completed using less advanced manufacturing technologies. Success in the niche markets requires high quality, unique products accompanied by fanatical attention to market development and customer service. Although these type of products violate the early criteria of only considering large volume users in response to the potential size of forest health and fire-risk reduction programs, their economic potential and social suitability are attractive enough to justify analysis.

Roundwood products present many economic advantages that make them an attractive product alternative. The cost to manufacture is low, but market value can be quite high. Small diameter logs in conventional pile, post and pole applications are valued at around \$200 per green ton. In contrast, this resource is worth roughly \$160 per green ton when processed into lumber or \$30 per green ton as chips (Wolfe, 2000). Poles and other high-value roundwood applications have a greater net value per volume because they require less processing, create less manufacturing-

related wastes, and have greater load-carrying capacity than lumber sawn from the same logs (Wolfe and Mosely, 2000).

Roundwood products may also be more compatible with the social concerns of the local communities. In the late 1980s and early 1990's, the wood processing industry of northern Arizona was dominated by one entity - Stone Container with a large newsprint facility and a sawmill. Although there were other users in the region, Stone's need for large quantities of wood coupled with the cash flow advantage of a well-capitalized large corporation, placed Stone in enviable position. They nearly controlled the market for saw logs and pulpwood coming from the federal forests in northern Arizona. This dominance had the secondary effect of unduly influencing forest management decisions. This situation is no longer, but its lessons are clear. Many do not want a repeat situation of a single, large wood fiber user controlling forest management via its control of the wood fiber market. An example of this community perspective can be gained by perusing the Grand Canyon Forests Partnership's literature. Although the GCFP has never formally publicized this concern about a large-scale wood products manufacturer, it is one of their goals to sustain forest restoration efforts through the creation of local, small-scale wood products industries (GCFP, 2001). By implication, their focus on small industry is in counter-response to the monopoly of the past.

To develop a better understanding of the opportunities and issues related to a roundwood cluster, an analysis of one potential cluster was completed and summarized here. This analyzed cluster is theoretical, but based upon real developments that are currently being undertaken by the Indigenous Community Enterprises (ICE), a non-profit initiative intent on developing and coordinating economic development projects with the Navajo Nation. Their first project is the Navajo Hogan/Roundwood Manufacturing Project that will manufacture affordable and modern hogan housing units from roundwood, along with other associated wood products (ICE, undated). At the time of this writing in the Summer of 2001, ICE is finishing the construction of their first hogan prototype and is beginning to develop their pilot manufacturing facility located in Cameron, AZ. ICE believes that the market for these hogan-building systems is very strong both on and off the Reservation. Their studies suggest that the Navajo Nation alone has a need for over 25,000 new homes of which a modern hogan is most desirable as it fulfills many cultural and ceremonial needs.

The theoretical cluster analyzed here is modeled partly after the ICE hogan manufacturing project by relying heavily on their hogan designs, sales projections, and current decisions about facility and equipment needs. The major difference between this analysis and the real project is that the theoretical model assumes a different mix of other products than what might really develop. The theoretical cluster focuses on a product mix that includes both developing and existing markets to optimize the use of the full range of logs coming from typical forest restoration and fuels reduction programs. In effect, this theoretical use cluster serves as a sort yard and eliminates the need to sort at the landing. This mix of uses includes:

- For logs cut from trees less than 8" dbh, on-site processing of firewood.
- For logs cut from trees 8" to 12" dbh, on-site manufacture of modern hogan building systems with the processed logs forming the load-bearing frame and wall enclosures.

- For logs from trees 13" dbh and larger, on-site processing of hand-peeled vigas or utility poles.

Small, modern hogans are the keystone product of this mix that controls the amount of raw material purchased and the operational characteristics of the cluster. The hogan product offering will be some variation of the designs being created by a team of architectural students and professors from School of Architecture at Arizona State University. Figure 4 is an early hogan concept showing the basic 25' diameter eight-sided hogan module along with a 10 ft x 10 ft module. These designs utilize four-inch and 6-inch diameter finished ponderosa pine logs as the building material for the structural frame and exterior walls.

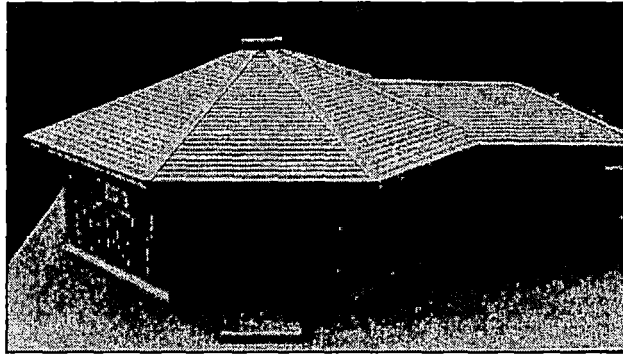


Figure 4. ICE Hogan Prototype

The analysis examined costs and net returns for a production sequence starting with 2 hogans per month through to a final production goal of 20 hogans per month. The cluster is assumed to be located at about 80 miles from Flagstaff in Cameron, AZ within a 14,440 square foot enclosed facility with outside concrete pad.

The basic 25' hogan frame with 529 square feet of useable space requires 820 cubic feet of input wood fiber from trees 8" to 12" dbh. This input wood fiber was estimated to cost a total \$72.80/ccf, which includes harvesting and trucking. Even though product recovery may increase over time with experience, the ratio of finish product volume to input wood volume was assumed constant at 50%. The manufacturing and sales personnel included a mill manager, a combined sales and design manager, mill workers, site crews to assemble the finished hogans at readied building sites, a skilled maintenance worker, and a clerical person. Their costs included a base salary plus health and insurance benefits. Capital improvements to the building and site were included at \$62,000 at start-up and an addition \$100,000 at full production. Facility site rental was estimated at \$5000 per month. Production equipment included pole debarker/processor, profile saw, strobe saw, container kiln, lift truck, front end loader, conveyors, and a variety of miscellaneous tools and equipment for a total initial investment of \$402,000. This equipment was depreciated over a 5 year service life on a straight-line basis and included a salvage value equaling 20% of the original costs. In addition, opportunity costs were assigned to the monthly fixed equipment costs; reflecting the loss of investment interest that the money spent to purchase the equipment could have yielded if invested instead.

The target sales price of \$30,000 was assumed for the basic octagonal structure that included a finished exterior structure with window and doors and a very basic insulated interior with painted drywall walls and baseboards, electrical fixtures and wiring, and basic plumbing for a kitchen sink. Costs associated with site preparation, foundation and floor slab, or utility hook-up are not included. This analysis only consider the basic hogan and did not account for the costs and returns associated with the additional rectangular module that could be provided to serve partly as a bathroom.

The firewood capacity was matched to the incoming wood needs for hogan production, utilizing that material coming from trees less than 8" dbh. Although a more local market for firewood might develop, this analysis assumed that small packaged bundles of split firewood could be sold to retailers in the Flagstaff and Phoenix areas for \$3.36 per 1.5' x 1.5' x 2' bundle. The assumed manufacturing equipment set-up included a gas-powered log splitter, chain saw, and other miscellaneous tools for a total initial investment of approximately \$10,000. This process was assumed be located outside the building on an adjacent concrete pad area. Except for a small amount of clerical time for billing and sales development, this cost center only accounted for direct operational costs and no overhead functions. As noted earlier, the hogan product line carried the facility and personal overhead costs.

Like firewood, the production capacity for hand-peeled vigas and poles was a function of the incoming wood supply as dictated by the hogan production capacity. The number of available larger logs for this high-value product was projected from inventory data collected from unit 2 of the GCFP's Research and Demonstration project. It is believed that this unit is fairly typical of the type of future stands that will be treated for ecological or fuels reduction purposes in northern Arizona. The treatment was a 2-4 presettlement prescription with a 22" dbh cutting limit designed by the Ecological Restoration Institute at Northern Arizona University. It was assumed that one person could process (buck to length and hand peel) 4 logs per day with minimal equipment costs. Like firewood, only a small amount of clerical/sales overhead was assigned to this cost center. Target sales price for these high-value logs was assumed at \$5 per cubic foot of finished product that has a small end diameter greater than or equal to 8" and a length greater than or equal to 20'.

This analysis assumes that reasonably located markets with the ability to pay the target sales price are readily available for all three product lines.

Table 10 summarizes the results of the theoretical cluster model on a monthly cost and net return basis. Additional details are provided in the appendix to this report. The tabulated summary costs include costs for raw logs at the manufacturing site in Cameron, fixed and operational manufacturing costs, other material costs, transport to market, site installation, sales expense, employee wages and benefits, and office and facility overhead. The projected employee totals of Table 10 are for personal directly employed by the cluster. It does not include those involve in trucking, which is assumed as a separate contract costing \$60/hour.

The results presented in Table 10 are very encouraging provided the previously noted key assumptions hold true. At a production capacity of 6 hogans per month, 357 bundles of firewood, and 155 large poles, the cluster moves from a deficit position into a break-even situation. The

production goal of 20 hogans per month, perhaps achievable within the third or fourth year of operation, provides an attractive net return that can be used to further grow and sustain the facility. As noted earlier, these types of products are small volume wood users. This analysis projects, at full capacity, a utilization rate of about 4200 ccf per year of wood fiber obtained from the restoration of about 260 acres of ponderosa forests.

	Start-up	Ramp-up Production	Mid-level production	Final goal
Basic 25' Hogan Structure				
Number of hogans per month	2	6	10	20
Total costs to process, etc. (\$/month)	-\$89,241.90	-\$170,891.73	-\$252,541.56	-\$458,700.08
Total sales revenue (\$/month)	\$60,000.00	\$180,000.00	\$300,000.00	\$600,000.00
Firewood				
Number of bundles per month	119	357	596	1192
Total cost to process, etc. (\$/month)	-\$1,585.71	-\$3,025.69	-\$4,467.54	-\$8,287.00
Total sales revenue (\$/month)	\$399.60	\$1,198.81	\$2,001.37	\$4,002.74
Hand-Peeled Poles				
Number of poles per month	52	155	258	516
Total cost to process, etc. (\$/month)	-\$3,297.97	-\$6,508.64	-\$9,719.30	-\$17,963.60
Total sales revenue (\$/month)	\$2,876.33	\$8,628.98	\$14,381.63	\$28,763.26
Cluster Summary				
Total costs (\$/month)	-\$94,125.58	-\$180,426.06	-\$266,728.40	-\$484,950.69
Total revenue (\$/month)	\$63,275.93	\$189,827.78	\$316,383.00	\$632,766.00
Net return (\$/month)	-\$30,849.65	\$9,401.72	\$49,654.60	\$147,815.31
Net return to input fiber (\$/cf)	-\$8.82	\$0.90	\$2.84	\$4.23
Number of full-time employees	6.23	10.29	14.35	23.71
Number of acres of fiber per month	2.20	6.59	10.98	21.97

Table 10. Projected Costs, Revenue, and Net Return for a Theoretical Roundwood Use Cluster in Northern Arizona

The development of the hogan product line, however, will face tremendous technical challenges; challenges that were not accounted in the cluster model via their potential demands on resources. These envision challenges include:

1. Roundwood structural system designs: The hogan frame design itself is still under development and will likely continue to be refined for many years in an effort to better serve a hopefully expanding customer base and to reduce costs by optimizing material use and reducing manufacturing complexities. This research and development work will rely heavily on the innovations and hard work of a staff of design, sales, and manufacturing personal. Except for the established log home market that use large diameter logs and the recent efforts of the USDA's Forest Products Laboratory to develop informational kiosks for the 2002 Winter Olympics in Salt Lake City, there are no roundwood structural designs to draw from. Similarly, very few engineers and architects are skilled in wood design and even fewer are comfortable with round sections.
2. Building code acceptance: As a load-bearing building system, hogans will face the additional sales-related hurdle of acceptance by local and regional building authorities. This acceptance may be accomplished by the validation of structural integrity through a systemic analysis

- completed by a licensed structural engineer that will require an on-going quality assurance program and the capability to produce professional construction drawings.
3. Log properties and design standards: A key component to validating structural integrity will be an assessment of processed log strength properties and long-term service behavior. Currently, very little is known about the strength and stiffness properties of small diameter round wood coming from the slow-growing ponderosa pine stands of northern Arizona. The existing national design standards for round timbers focus on large round wood members acting in bending with design values derived from small-scale, clear-wood, dry specimens of old-growth wood. These procedures do not readily apply to structural round wood cut from small diameter, young trees that will be used in axial tension or compression applications.
 4. Connections: The evolution of wood structures during the past 150 years has concentrated on sawn lumber (Wolfe, 2000) at the expense of round wood developments. The technology of connecting two round wood pieces together has been ignored. Round wood connections, however, are a critical component to the successful development of any round wood structural system including the hogan system.
 5. Processing: Although some small-diameter round wood can be used in the raw form, high-valued engineering applications like the hogan system, will require precision manufacturing and drying. Up until recently, round wood processing technologies have not produced products with high uniformity in dimension. Increased attention must be given new manufacturing techniques and to monitoring and controlling product behavior during and after processing to ensure a high-quality product that can, indeed, demand a higher value in the market.

DECISION MATRIX RESULTS AND DISCUSSION

According to the information revealed in the previous product-by-product discussion, the authors were able to comparatively judge product performance. The criteria scoring results are provided in Table 11. After the assignment of criteria scores, total un-weighted and weighted product scores were determined and subsequent ranks set.

This decision methodology, as reported in Table 11, suggests that mechanical pulp is the most suitable product choice for meeting the conditions unique to northern Arizona. Regardless of summation scheme, it achieved a ranking of 1. This result points to the product's potential for efficiently utilizing small diameter wood material of low value to produce a highly valued product with a strong market outlook, while providing a substantial number of jobs to the local economy. It is a high-tech solution that with high energy demands. Its environmental shortcomings can be mitigated.

The roundwood cluster edged out particleboard and MDF products because of its high ratings in the criterion of initial costs/flexibility, discharge, water usage, and $9'' \leq \text{dbh} < 12''$ that compensated for its low potential in revenue, jobs, and market outlook. The roundwood products examined find its buyers in niche, small-scale market segments that become quickly oversupplied, but are demanding markets in terms of quality, uniqueness, and attention to customer service. On the other hand, these types of cluster uses are appealing because they present less capital and social risk. The roundwood cluster analyzed here could be established for less than \$750,000, while today's large-scale commodity type products are produced in facilities costing between 50 to 100 million dollars. In addition, individual small scale wood

users have almost no ability to influence the market price for raw logs; an attribute that is perceived as desirable by the local community.

			A	B	C	D	E	F	G
	Criteria	Wts. (%)	OSB	Plyw'd	Part'bd	Lumber & Boards	Mech. Pulp	Ethanol	Round Wood
1	Initial Cost/Flexibility	12.5	3	4	3	4	4	2	5
2	Discharge	6.25	3	3	3	4	2	3	4
3	Water Usage	6.25	3	3	3	3	2	1	5
4	Wood Properties	12.5	3	1	3	2	3	3	3
Size Suitability:									
5	Slash, B&N	6.25	3	3	3	3	3	4	3
6	3" ≤ dbh < 5"	6.25	3	3	4	3	4	4	3
7	5" ≤ dbh < 9"	12.5	3	1	3	2	3	3	3
8	9" ≤ dbh < 12"	6.25	3	2	3	4	3	3	4
9	Revenue Potential	12.5	3	1	2	2	4	1	2
10	Jobs	6.25	3	3	3	3	3	3	1
11	Market Outlook	12.5	3	1	3	3	4	2	1
	Total Raw Score		33	25	33	33	35	29	34
	Rank*		3	5	3	3	1	4	2
	Total Weighted Score		30.00	20.63	29.38	28.75	33.13	25.00	30.00
	Weighted Rank*		2	6	3	4	1	5	2

*Ranking ranges from 1 to 7, with 1 being best.

Table 11. Completed Decision Matrix Comparing the Suitability of Uses

Particleboard and medium density fiberboard products and OSB were judged nearly equal in their suitability. The demand and revenue outlook for both non-structural and structural panels is dependent upon the construction industry, which is projected to shift over the next 20 to 50 years more towards renovation and remodeling away from new construction.

Lumber and boards was deemed a marginal product opportunity by this analysis. This ranking reflects the processing and grade recovery problems presented by the inherent growth and strength characteristics of black jack ponderosa pine. It is of low strength and consequently does not benefit from value-adding techniques such as machine stress rating for structural applications. Its cross-section is largely juvenile wood that if not handled and dried properly, will result in substantial grade degradation. On the other hand, high-speed modern sawmills with scanning and optimizing technologies have been proven successful with small-diameter logs of a variety of species. If the drying and degrade issues can be controlled, the blackjack resource may have some opportunity as cut stock in the appearance grade board market.

Ethanol's low ranking reflects its poor revenue potential and market outlook, as well as its need to be located at an existing power plant and its tremendous demand for water. In addition, the technology to convert wood fiber into ethanol is still under development and has yet to be proven out in any large-scale way. Although it is the one use that could convert slash, bark, needles to a useable product, it is judged a product unsuitable to the conditions of northern Arizona.

Similarly, plywood is deemed unsuitable. It was ranked last by both summation techniques; pointing the product's need for high quality, large diameter logs and species with higher strength characteristics than that provided by small diameter logs of young ponderosa pine. It also reflects the shifting market where cheaper OSB is the preferred alternative over plywood in structural panel applications.

CONCLUSIONS

This study used a decision-making technique, called the decision matrix, to analyze wood fiber uses and to answer the question:

What market or combination of wood fiber uses can effectively and suitably meet the conditions unique to northern Arizona?

By evaluating the relative performance of a six logical products to a benchmark product within eleven categories ranging from revenue potential to raw material compatibility to infrastructure flexibility, we found that large-scale commodity type products dominated. Mechanical pulp and its related paper and board products were judged as the most suitable product opportunities. Two of three panel products, OSB and the non-structural grouping of particleboard and MDF, followed closely behind. They are judge suitable because of their ability to convert large quantities of small diameter ponderosa pine with objectionable growth characteristics into high value product, while providing better paying employment opportunities. These types of commodity markets, however, are vulnerable to complex demand and supply problems. They typically overbuild their production capacity during times of high product demand that eventually results in oversupply and price compression. This cyclic behavior reflects back into the community through production slowdowns, short or long term layoffs, and demands for cheaper raw materials.

Small-scale roundwood uses were also judged suitable. Even though this study evaluated only one mix of products (firewood, hogans, hand-peeled vigas and poles), we believe that the conclusions drawn about this mix are relevant to other small-scale product uses. It represents the type of specialty niche market that is small in scale, requires less up-front capital investment, but demands high quality and attention to customer service. Roundwood use clusters can convert only small quantities of wood fiber into value-added products. As a result, their ability to sustain large-scale forest health and fuels reduction programs within the region's national forest will be limited.

Because of the current lack of suitable wood fiber markets, the ability of the region's national forest systems to fund thinning projects depends heavily on federal appropriations provided for fire reduction goals. These appropriations will eventually dry up. The need to thin, however, will grow stronger, while the ability to do is diminished unless alternative funding mechanisms are found. Wood product industries provide that alternative funding through the purchase of thinning by-products. In effect, the manufacture of suitable wood-based products *is the necessary component for sustaining forest health and fuels reduction programs*. Their establishment, however, relies heavily on the availability of a steady supply of fiber of sufficient quantity.

LITERATURE CITED

- American Plywood Association. 1997. Plywood design specification. January. 7011 So. 19th St. P.O. Box 11700. Tacoma, WA 98411-0700.
- Arganbright, D.G.; Venturino, J.A.; Gorravadm M. 1978. Warp reduction in young-growth ponderosa pine studs dried by different methods with top-load restraint. *Forest Products Journal* 28(8): 47-52.
- Bendsten, B.A. 1978. Properties of wood from improved and intensively managed trees. *For. Prod. J.* 28(10): 61-72.
- Bennett, S. 1996. Telephone conversation, Stone Container Corporation, Flagstaff, AZ, Sept. 11.
- Blake, B.R.; Voorhies, G. 1980. Kiln drying of young-growth ponderosa pine studs. *Arizona Forestry Notes* 13. Flagstaff, AZ: School of Forestry, Northern Arizona University.
- Biofuels News. 1998. Fueling the environment: Switchgrass research review, Midwest Research Institute, Vol. 1, No. 4. National Renewable Energy Laboratory, Golden, CO.
- Bullock, D. 1996. Interview and tour, Louisiana-Pacific Corporation, Production Superintendent, Chilco, ID, May 20.
- Cannell, E.; Cockram, R. 2000. The future of BCTMP. *Pulp & Paper*. May.
- Cisternas, A.G. 2000. Mechanical properties of ponderosa pine dimension lumber from small-diameter, over-stocked stands in Arizona. Draft - Thesis for Degree of MS. Dept. of Forest Products, Un. of Idaho, Moscow, ID. May.
- County Business Patterns. 1988. Counties – Employees, payroll, and establishments by Industry: 1986. U.S. Census Bureau.
- County Business Patterns. 1996. 1996 County business patterns for Coconino, AZ. U.S. Census Bureau. <http://www.census.gov/>
- Dramm, J. 1999. Sustainable forestry in Arizona, New Mexico, and Utah: Ecology, Economy, and Community. Trip report. Madison, WI: USDA, FS, FPL, State & Private Forestry, Technology Marketing Unit. February.
- Fahey, T.D. and J.K. Ayer Sachet. 1993. Product recovery of ponderosa pine in Arizona and New Mexico. Res. Pap. PNW-RP-467. USDA, Forest Service, Pacific Northwest Research Station. Portland, OR. 18 pp.
- Forest Products Laboratory. 1999. Wood handbook – Wood as an engineering material. Gen. Tech. Rep. FPL-GTR-113. Madison, WI: USDA, Forest Service, Forest Products laboratory. 463 p.

Gorman, T.M.; Green D.W. 2001. Structural lumber from small-diameter western U.S. softwood trees. ASCE Structural Engineering Institute Conference Proceedings. Washington, D.C. May.

Gorman, T.M. 2001. Mechanical properties of ponderosa pine dimension lumber from small diameter, overstocked stands in Arizona. 97-RJVA-2975, Final report. Dept. of Forest Products, Un. of Idaho, Moscow, ID.

Grand Canyon Forests Partnership. Unknown-a. Flagstaff area wildfire risk assessment. <http://www.gcfp.org/firerisk.htm>

Grand Canyon Forests Partnership. Unknown-b. Flagstaff area wildfire risk assessment. http://www.gcfp.org/flag_plan.htm

Grand Canyon Forests Partnership. 2001. A guide to the Grand Canyon Forests Partnership. May. <http://www.gcfp.org/guide.htm>

Haygreen, J.G.; Bowyer, J.L. 1996. Forest products and wood science, 3rd ed. Iowa State University Press, Ames, Iowa 50014.

Haynes, R.W. 2001. The 2000 RPA timber assessment: An analysis of the timber situation in the United States, 1996-2050. Draft. January. <http://www.fs.fed.us/pnw/sev/rpa/rpa2000.htm>

Indigenous Community Enterprises. Undated. Navajo Hogan/Roundwood Manufacturing Project. School of Forestry, Northern Arizona University, www.cba.nau.edu/ICE/project_summary.htm (7/25/01).

Irland Group. 1991. Market conditions, outlook, and implications for the TNF, appendix to 301(e) report. Irland Group, Augusta, ME.

Kane, S.; LeBlanc, M. 1989. Ethanol and US Agriculture, USDA, Agriculture Information Bulletin, Number 559, 8p.

Kepner, C.H.; Tregoe, B.B. 1965. The rational manager. McGraw-Hill, New York, NY.

Kryzanowski, T. 1998. From wood waste to ethanol fuel. Logging & Sawmilling Journal. May. 39-42.

Larson, D.; Mirth, R. 1998. Potential for using small-diameter ponderosa pine: a wood fiber projection. Forest Products Journal. 48(6): 37-42.

Larson, D.; Mirth, R. 1999. Opportunities for funding wildland-urban interface fuels reduction programs. Flagstaff AZ: Department of Civil and Environmental Engineering, Northern Arizona University, April.

- Larson, D.; Mirth, R.; Ellis, J.; Carey, K. 2001. Fort Valley 10K units 13-16: Inventory, implementation, and revenue. Flagstaff AZ: Department of Civil and Environmental Engineering, Northern Arizona University, September.
- Lowell, E.C.; Green, D.W. In Press. Lumber recovery form small-diameter ponderosa pine from Flagstaff, Arizona. Gen. Tech. Rep. RMRS-GTR-xxx. Fort Collins, CO: USDA, Forest Service, Rocky Mountain Research Station.
- Lynch, D.L.; Romme, W.H.; Floyd, M.L. 2000. Forest restoration in Southwestern ponderosa pine. *Journal of Forestry*. August. pp. 17-24.
- Mackay, J.F.G.; Rumball, B.L. 1972. Plasticizing distortion-prone softwood studs prior to high temperature seasoning. *Forest Products Journal*. 22(6): 27-28.
- Maeglin R.R. 1987. Processing and products considerations critical in utilizing second-growth ponderosa pine. *Proceedings: Ponderosa pine – the species and its management*. Sept. 29 – Oct. 1, Spokane, WA and Pullman, WA, Washington State University. 19-24.
- Markstrom, D.C.; Shuler, C.E.; King, R.M. 1984. Warpage of studs from young growth ponderosa pine from Northern New Mexico. Res. Pap. RM-257. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.
- Mater Engineering. 2001. GCFP wrap-up of implementation project report. July. Corvallis, OR.
- McAlister, R.H.; Clark, A. 1991. Shrinkage of juvenile and mature wood of loblolly pine from three locations. *For. Prod. J.* 42(7/8): 25-18.
- McAlister, R.H.; Clark, A. 1992. Effect of geographic location and seed source on the bending properties of juvenile and mature loblolly pine. *For. Prod. J.* 41(9):39-42.
- McLaren, J.; DeKing, N.; Rudder, G.; Mackenzie, K.; Jensen, K. 2000. An upcycle in 1999 simmers in 2000 as paper grades face mixed markets; mergers continue. *Pulp&Paper*, August.
- Miller Freeman, Inc. 1997. Pulp & paper 1998 North America factbook. 600 Harrison Street, San Francisco, CA 94107.
- Mirth, R.; Larson, D. 2000. Air drying small diameter round timber, data collection and observations. Department of Civil and Environmental Engineering, Northern Arizona University, February.
- Paperloop. 2002. Aspen Bay Pulp and Fibre financing nears completion. News & Information Services. Miller Freeman, Inc. <http://paperloop.com>
- Polzin, P.E. 1994. Spatial distribution of wood products industries. *Journal of Forestry*, 92(5)., May. pp. 38-42.

Pugel, A.D.; Price, E.W.; Hse, C.Y. 1989. Composites from southern pine juvenile wood. Part I. For. Prod. J. 40(1): 29-33.

Pugel, A.D.; Price, E.W.; Hse, C.Y. 1990. Composites from southern pine juvenile wood. Part II. For. Prod. J. 40(3): 57-61.

Pugh, S. 1995. Total design. Addison-Wesley Publishing Co.

Quincy Library Group. 1997. Northeastern California ethanol manufacturing feasibility study. November. http://www.qlg.org/pub/act_acp/ethanol/feasibility.htm

Random Lengths. 1998. Big Book. P.O. Box 867, Eugene, OR 97440-0867.

Random Lengths. 1999. OSB output likely to top plywood. June 18. P.O. Box 867, Eugene, OR 97440-0867.

Random Lengths. 2000. OSB market braces for new production. July 21. P.O. Box 867, Eugene, OR 97440-0867.

Random Lengths. 2001. Price guide. June 8. P.O. Box 867, Eugene, OR 97440-0867.

Rendle, B.J. 1960. Juvenile and adult wood. J. Inst. Wood Sci. 5:58-61.

Reitman, V. and N. Christian, 1997, Chrysler plans on minivans using ethanol, Wall Street Journal, June 10, p. A3.

Rosenfield, P. 1994. Potential utilization of small diameter trees in Sierra county public lands. University of California Berkeley, Dept. of Environmental Sciences, Policy, and Management, 105 p.

Schuler, A; Adair, C. 2001. Supply and demand: The outlook for North American structural wood panels. Engineered Wood Journal. 4(1), Spring. American Plywood Association. <http://www.apawood.org/>

Senft, JF; Bendtsen, B.A; Galligan, W.L. 1985. Weak wood: Fast grown trees make problem lumber. J. of For. 83(8):477-484.

Senft, JF; Quanci, J.J; Bendtsen, 1986. Property profile of 60-year old Douglas-fir. In Juvenile Wood – What does it mean to forest management and forest products? For Prod. Res. Soc. Proc. 47309.

Southwest Forest Alliance. Unkown. Why the flagstaff pre-settlement restoration model should not be applied to public forest lands? P.O Box 1948, Flagstaff, AZ, 86002. http://www.swfa.org/restoration_booklet_files/cover.html

Spelter, H. 1996. Capacity, production, and manufacture of wood-based panels in the United States and Canada, USDA, Forest Products Laboratory, FPL-ETR-90, Madison WI, 17 p.

Spelter, H.; Wang, R.; Ince, P. 1996. Economic feasibility of products from Inland West small-diameter timber, USDA, Forest Service, FPL-GTR-92. Madison, WI, 17 p.

Spelter, H. 1999. Boardtalk: Wood summit focuses on fiber, supply, market conditions. PanelWorld. July. pp. 14-15.

Temple, R.; Gagnon, R.; Harrinton, S.; Bailey, J.; Kim, Y.S.; Larson, D.; Zipse, B. 1999. Assessment of forest resources and communities in the Four Corners region. Report to the Four Corners Sustainable Forestry Initiative. August.

Ulrich, K.T.; Eppinger, S.D. 2000. Product design and development. 2nd Ed. Irwin McGraw-Hill.

US Department of Energy, 1993, Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Section, Technical Report Eleven: Evaluation of Potential Wood-to-Ethanol Process, Washington, DC.

Voorhies, G.; Groman, W.A. 1982. Longitudinal shrinkage and occurrence of various fibril angles in juvenile wood of young-growth ponderosa pine. Arizona Forestry Notes No. 15. 11 pp. February. Northern Arizona Univ., Flagstaff, AZ.

Voorhies, G.; Jameson, D.A. 1969. Fiber length in southwestern young-growth ponderosa pine. For. Prod. J. 19(5):52-55.

Wagner, F.G.; Keegan, C.E.; Fight, R.D.; Willits, S. 1998. Potential for small-diameter sawtimber utilization by the current sawmill industry in western North America. Forest Prod. J. 48(9): 30-34.

Wagner, F.G.; Fiedler, C.E.; Keegan, C.E. 2000. Processing value of small-diameter sawtimber at conventional stud sawmills and modern high-speed, small-log sawmills in the western United States – a comparison. Western Journal Applied Forestry 15(4): 208-212.

Western Wood Products Association. 1995. Ponderosa pine taken from WWPA's Ponderosa pine species facts, August. <http://www.wwpa.org/ppine.htm>

Willits, S.; Barbour, R.; Tesch, S.; Ryland, D.; McNeel, J.; Fight, R.; Kumar, S.; Myers, G.; Olson, B.; Mason, A. 1996. The Colville study: Wood utilization for ecosystem management, preliminary results of study of product potential from small-diameter stands, USDA Forest Service, Forest Products Laboratory, FPL-RP-559, Madison, WI, 11 p.

Wolfe, R. 2000. Research challenges for structural use of small-diameter round timbers. Forest Prod. J. 50(2): 21-29.

Wolfe, R., C. Mosely. 2000. Small-diameter log evaluation for valued-added structural applications. *Forest Prod. J.* 50(10): 48-58.

Yancey, M., 1999, Memo to D. Larson on Northern Arizona Biomass-to-Ethanol, Single-Stage Dilute Nitric Acid Hydrolysis Process Manufacturing Costs, NREL Biofuels Program, February, 9.

APPENDIX: ROUNDWOOD CLUSTER ANALYSIS DETAILS

Summary Calculation Sheet Shown for Production Capacity of 10 Hogans per Month

Liveable Area (sq. ft.)		529
Log Materials Estimate for 1 hogan		
Finished Log, 6" (lineal feet)		2011
Finished Log, 4" dia (lineal feet)		170
Log recovery		50%
Raw log estimate (cf) from 8" to 12" dbh trees		819.33
Basic Log Harvesting Costs (\$/ccf)		\$40.00
Trucking Costs:		
Loading & unloading (\$)	50	\$100.00
Number of miles to mill		80
Hourly rate (\$/hr)		\$60.00
Total cost per truck (\$)		\$334.55
Number of trucks		0.80
Total trucking costs		\$268.73
Total costs for raw logs at Mill (\$) for one hogan		\$596.46
Manufacturing costs for raw frame per year:		
Production capacity (# hogans/month)		10
Number of operational months		11
Number of hours per week		40
Average number of weeks/month		4.25
Mill operating costs per year		\$281,025.27
Personal costs per year:		
Mill manager	1	\$85,350.00
Sales & Engineering manager	1	\$85,350.00
Mill workers	5	\$119,703.38
Maintenance	1	\$31,920.90
Clerical	1	\$23,940.68
Total personal costs per year		\$346,264.95
Miscellaneous office expenses per year		\$12,000.00
Building & site rental		\$60,000.00
Raw log costs		\$65,610.59
Total raw frame costs per year		\$764,900.81
Hogan finish work per year		
Hogan Exterior (per Hogan)		\$7,569.56
Hogan Interior (per Hogan)		\$21,447.24
Total estimate for finish work per year		\$3,191,848.87
Trucking kit to site (200 miles one way)	200	\$723.33
Total trucking per year		\$79,566.67
Installation at site (foundation already built)		
1 week, 2 men per hogan per year		\$112,662.00
Per deim and hotel expenses per year		\$63,250.00
Total yearly operating + manufacturing costs		\$4,212,228.35
Additional sales expense (2% of costs)		\$84,244.57
Total		\$4,296,472.92
Percent profit (10% of costs)		\$429,647.29
Total		\$4,726,120.21

Cost per hogan (excludes utilities, site work, foundation)		\$42,964.73
Pricing goal for raw hogan		\$30,000
Total raw frame costs per year		\$764,900.81
Hogan Exterior (per Hogan)		\$7,569.56
Hogan Interior - reduced (per Hogan)		\$8,443.00
Total finish (reduced interior) per year		\$1,761,382.14
Trucking and set-up costs per year		\$255,478.67
Costs summary (excluding profit and sales costs)		\$2,781,761.62
Additional sales costs (2% of costs)		\$55,635.23
Subtotal		\$2,837,396.85
Profit available per year		\$462,603.15
Firewood (capacity matched to hogan fiber input)		
Log estimate from 5" to < 8" dbh (ccf/month)		21.04
Log cost (\$/month)		\$841.41
Log trucking costs per month		\$689.92
Number of chords/month (1.27 area variance)		16.56
Processing (buck, split, stack for 1 laborer, chords/day)		5
Number of hours for one processor		26.50
Bundle and wrap (chords/day)		8
Number of hours to bundle and wrap		16.56
Number of 1.5' x 1.5' x 2' bundles per chord (1.27 area adj)		36.00
Total bundles per month		596.00
Labor costs (\$/month)		\$551.33
Material costs per bundle		\$0.50
Material costs (\$/month)		\$298.14
Equipment costs (\$/month)		\$759.88
Loading and trucking to market		
one truckload, average number of miles one way	220	\$670.00
# bundles per truck	10	360
# trucks per month		1.66
trucking costs (\$/month)		\$1,109.22
Sales/clerical (\$/month)	0.1	\$217.64
Total monthly estimate on costs		\$4,467.54
Monthly costs on a per bundle basis		\$5.90
Target sales price at retailer per bundle		\$3.65
Mark-up at 8%		0.292
Price to producer		\$3.36
Profit per bundle		-\$2.54
Vigas and Poles (hand-peeled, matched to hogan) w/o 16" cap		
Raw log quantity (ccf/month)		71.96
Log cost (\$/month)		\$2,878.36
Log trucking costs per month		\$2,360.15
Nos of poles/month (8" dib and greater at 20' or longer)		258.13
Pole quantity in cf of pole/month		2876.33
Processing (buck, & hand peel, 1 person, # poles/day)		4
Number of hours for one processor per month		64.53
Labor costs (\$/month)		\$826.19
Equipment costs (\$/month)		\$1,547.60
Loading and trucking to market		
one truckload, average number of miles one way	220	\$670.00

# trucks per month		2.82
trucking costs (\$/month)		\$1,889.35
Sales/clerical (\$/month)	0.1	\$217.64
Total monthly estimate of costs		\$9,719.30
Target sales price (\$X/cf of finished pole) per month	5	\$14,381.63
Monthly profit		\$4,662.33
Vigas and Poles (hand-peeled, matched to hogan) w/ 16" cap		
Raw log quantity (ccf/month)		25.01
Log cost (\$/month)		\$1,000.46
Log trucking costs per month		\$820.34
Nos of poles/month (8" dib and greater at 20' or longer)		132.91
Pole quantity in cf of pole/month		1035.81
Processing (buck, & hand peel, 1 person, # poles/day)		4
Number of hours for one processor per month		33.23
Labor costs (\$/month)		\$425.40
Equipment costs (\$/month)		\$1,512.38
Loading and trucking to market		
one truckload, average number of miles one way	220	\$670.00
# trucks per month		1.02
trucking costs (\$/month)		\$680.38
Sales/clerical (\$/month)	0.1	\$217.64
Total monthly estimate of costs		\$4,656.62
Target sales price (\$X/cf of finished pole) per month	5	\$5,179.05
Monthly profit		\$522.43
Cluster summary (per month)		
Nos of hogans per month		10
Total hogan manufacture & sales w/ reduced interior		-\$236,449.74
Total hogan sales per month		\$300,000.00
Bundles of firewood per month		596.00
Total firewood processing & sales cost		-\$4,467.54
Total firewood sales to retailer		\$2,001.37
Nos of large poles per month (w/o 16" cap)		258.13
Total pole processing & sales cost		-\$9,719.30
Total pole sales per month		\$14,381.63
Nos of large poles per month (w/ 16" cap)		132.91
Total pole processing & sales cost		-\$4,656.62
Total pole sales per month		\$5,179.05
Total costs w/o 16" cap per month		-\$250,636.58
Total sales w/o 16" cap		\$316,383.00
Net (profit) w/o cap per month		\$65,746.42
Return to input fiber (net \$/input cf)		\$3.76
Total costs w/ 16" cap		-\$245,573.89
Total sales w/ 16" cap		\$307,180.42
Net (profit) w/ cap per month		\$61,606.53
Return to input fiber (net \$/input cf)		\$3.52
Number of full time employees (excluding truck drivers)		14.35
Number of acres of fiber per month based on unit 2		10.98

Building and Equipment Worksheet

Manufacturing Facility Capital Cost @ R&D Site				final goal
Building size (sq. ft.)		14400		
Outside Pad (sq. ft.)		14400		
Site & Building Improvements (\$)		\$62,000.00	additional	\$100,000.00
Site & Building Rental per month, per year	5000	\$60,000.00		
Equipment				
Pole Debarker/Processor:				
Montana manufacturing		\$80,000.00		
Dowel Mill 4" to 8" Capacity		\$3,500.00		
100 HP Electric Motor		\$1,200.00		
15 HP Electric Motor		\$10,000.00		
20' Line Chain Infeed Conveyor		\$3,500.00		
20' Outfeed Conveyor Belt		\$3,500.00		
Knives & Grinder		\$2,500.00		
Shipping		\$2,000.00		
Disconnect		\$2,500.00		
Total:		\$108,700.00		
Pendu # 4300 Profile Saw:				
Saw		\$85,300.00		
20' Roll Case Infeed Confeyor		\$8,500.00		
20' Fough Belt Outfeed Conveyor		\$8,500.00		
2 - Log House Saw Blades		\$15,760.00		
Lockout panel		\$12,100.00		
Bearing assembly		\$7,050.00		
Shipping & installation	5%	\$6,860.50		
Total:		\$144,070.50		
Strobe Saw		\$2,000.00		
Woodmizer Container Kiln:				
Kiln		\$25,000.00		
Shipping		\$1,500.00		
Installation		\$1,500.00		
Total:		\$28,000.00		
Dust collection system		\$12,750.00		
Small Misc Equipment				
225 VAC/125 VDC Welder		\$750.00		
OXT/ACT/Cutting Torch Kit		\$850.00		
Metal Cutoff Saw		\$550.00		
Hand Drills		\$400.00		
7-1/4" Skillsaw		\$200.00		
Banding Tool and Steel Strapping		\$2,000.00		
Misc. Tools		\$2,000.00		
Total:		\$6,750.00		
Standard Tools				
Radial Arm Saw		\$7,000.00		
12" Compound Miter Saw		\$750.00		

20" Heavy Duty Bandsaw		\$1,700.00		
Mini Milling machines (2)		\$1,100.00		
3 Roll Motor Drive feeder		\$1,700.00		
20' Drill press		\$1,500.00		
14" Table Saw		\$3,350.00		
13" Planer/Moulder		\$1,050.00		
16" Straight Knife Planer		\$3,200.00		
5 HP 50 Gal Air Compressor		\$2,500.00		
Shipping and Installation	5.00%	\$1,192.50		
Total:		\$25,042.50		
Yard Equipment				
Hyster Lift Truck w/ attachments		\$25,000.00		
John Deere Front End Loader		\$50,000.00		
Total:		\$75,000.00		
Yearly Operating Costs for Big Items				
Big Item Equip + Site Improv		\$457,563.00	\$395,563.00	\$557,563.00
Service life (yrs)		5		5
Salvage value (20%)		\$91,512.60		\$111,512.60
Depreciation		\$73,210.08		\$89,210.08
Opportunity Costs (9% of AVI)		\$28,002.86		\$34,122.86
Insurance costs (1.5% of AVI)		\$4,667.14		\$5,687.14
Taxes (25% of Depreciation)		\$18,302.52		\$22,302.52
Maintenance & Repair (50% of Equip Depr)	\$63,290.08	\$31,645.04		
Power costs:				
Dryer (\$400/hogan set)		\$44,000.00		
Pole Debarker		\$14,666.67		
Pendu Saw		\$14,666.67		
Lights, etc.	0.04	\$13,824.00		
Regular Maintenance:				
Saw Blades		\$8,000.00		
Knife Sharpening		\$2,500.00		
Fuel Costs:				
Hyster Lift Truck (50% utilization)	0.06	\$4,692.00		
Front End Loader (80% utilization)	0.06	\$7,507.20		
Tires (1 set)		\$1,884.00		
Lube, Oil & Filters (.5 of fuel costs)		\$6,099.60		
Total Yearly Operating Cost for Big Equip		\$273,667.77		\$300,807.77
Operating costs per hour:		\$146.35		
Yearly operating for misc tools				
Service life (yrs)	1			
Opportunity costs		\$607.50		
Maintenance & Repair (100% of initial costs)		\$6,750.00		
Total yearly operating costs		\$7,357.50		
Operating costs per hour		\$3.93		
Firewood equipment				
wood splitter		\$7,500.00		
bander		\$750.00		
chain saw		\$1,000.00		

safety gear		\$500.00		
miscellaneous		\$1,000.00		
Total guess		\$9,750.00		
Service life	1			
Opportunity costs		\$2,253.83		
Maintenance & Repair (50% of initial costs)		\$4,875.00		
Total yearly operating costs		\$7,128.83		
Operating costs per hour		\$3.81		
Fuel, lube & oil per hour		\$4.22		
total estimate per hour of operation		\$8.03		
Pole peeling operation				
chain saw		\$1,000.00		
miscellaneous		\$1,000.00		
safety gear		\$500.00		
total equipment		\$2,500.00		
opportunity costs		\$225.00		
maintenance & repairs (50% of initial)		\$1,250.00		
fixed operating costs per year		\$1,475.00		
Operating costs per hour		\$0.79		
fuel, lube & oil per hour		\$1.13		

Labor Worksheet

Manufacturing Manager	Yearly Base Salary		\$60,000.00
	Medical (11% of base)		\$6,600.00
	Workman's Comp (28% of base)		\$16,800.00
	Long term Disabil (.5% of base)		\$300.00
	Retirement (2.2% of base)		\$1,320.00
	Sick leave (.55% of base)		\$330.00
	Total yearly costs		\$85,350.00
Sales& Engineering Manager	Yearly Base Salary		\$60,000.00
	Medical (11% of base)		\$6,600.00
	Workman's Comp (28% of base)		\$16,800.00
	Long term Disabil (.5% of base)		\$300.00
	Retirement (2.2% of base)		\$1,320.00
	Sick leave (.55% of base)		\$330.00
	Total yearly costs		\$85,350.00
Manufacturing Labor	Hourly base (\$/hr)	\$9.00	
	Yearly base		\$16,830.00
	Medical (11% of base)		\$1,851.30
	Workman's Comp (28% of base)		\$4,712.40
	Long term Disabil (.5% of base)		\$84.15
	Retirement (2.2% of base)		\$370.26
	Sick leave (.55% of base)		\$92.57
	Total yearly costs for one		\$23,940.68
	Number		7
	Total yearly costs		\$167,584.73
Clerical	Hourly base (\$/hr)	\$9.00	
	Yearly base		\$16,830.00
	Medical (11% of base)		\$1,851.30
	Workman's Comp (28% of base)		\$4,712.40
	Long term Disabil (.5% of base)		\$84.15
	Retirement (2.2% of base)		\$370.26
	Sick leave (.55% of base)		\$92.57
	Total yearly costs		\$23,940.68
	Number		1
	Total yearly costs		\$23,940.68

Maintenance	Hourly base (\$/hr)	\$12.00	
	Yearly base		\$22,440.00
	Medical (11% of base)		\$2,468.40
	Workman's Comp (28% of base)		\$6,283.20
	Long term Disabil (.5% of base)		\$112.20
	Retirement (2.2% of base)		\$493.68
	Sick leave (.55% of base)		\$123.42
	Total yearly costs for one		\$31,920.90
	Number		1
	Total yearly costs		\$31,920.90